Alive and Inseparable

British Columbia's Coastal Environment:
2006

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Executive Summary

The six technical papers in this volume constitute a key deliverable for a project reporting on the coastal environment of British Columbia. The project started in 2004 and was planned and funded in collaboration with Fisheries and Oceans Canada, the University of British Columbia Fisheries Centre, and the University of Victoria Geography Department, with key contributions from Environment Canada. The reporting focused on a region extending westward from the height of the Coast Mountains and included the marine area within Canada's 200-mile limit.

Each paper provides an overview of the issues, a set of indicators, and a summary of results. Each paper also contains a section describing what is currently being done to address the issues and a section with suggestions for what individuals can do. The indicators in the reports were selected and developed in consultation with scientists and technical experts as well as representatives of target audiences. Each indicator includes background information, data sources, and a description of the methods of analysis, including caveats and assumptions.

This set of papers is one of a suite of deliverables from the project. All results, including the full text of the papers and the data sets underlying the graphs, are also available to the public on the project website (*www.env.gov.bc.ca/soe/bcce/*). The website provides accessible summaries of key information and links to other information sites for further reference. A folding poster brochure was also produced as a means of interesting the public in going to the website to learn more.

SUMMARY OF KEY RESULTS

Population and Economic Activity

Over the next 20 years, the coastal population is projected to increase by a million people, increasing pressure on the environment through land-use changes and water demand, discharge of sewage and other waste, and emissions of pollutants. Industries such as forestry, fishing, and tourism depend on healthy ecosystems, yet most economic activities have some kind of impact on those ecosystems, either temporary or permanent.

- Population pressure on the environment is greatest on BC's southwest coast, where 76% of the population lives.
- Only 2% of the land area of the province as a whole has been permanently altered by human uses (such as housing, transportation, agriculture). In the Greater Vancouver Regional District, however, more than 40% of the land area is occupied by such uses.
- The rate of land use change in the GVRD was lower in the period 1998 to 2002 than in the previous 5 years, during which there was a large increase in urban area and loss of forests, agricultural land, and some wetlands. Currently, standing forest covers about 40% of the GVRD.

- The highest volume of sewage is discharged in the Georgia Basin; daily volumes increased by more than 60% between 1983 and 1999. Closure of coastal shellfish harvesting areas due to sewage contamination continues to increase; in 2004, more than half (58%) of the shellfish harvesting areas in the Georgia Basin were closed.
- In 1999, the proportion of population served by secondary sewage treatment more than tripled (to 54%) when the Annacis Island Wastewater Treatment Plant in the Fraser Valley was upgraded.
- Since the 1800s, about 20% of BC's coastal land area has been disturbed by human activity (logging, agriculture, and urbanization) and natural events (fire and insect outbreaks). In the mid-1990s, 41% of the coastal land area was covered by forests over 140 years old and 7% was covered by forest that had been logged or burned within the past 20 years.
- More large estuaries on the coast have economic tenures in the intertidal area than conservation tenures, but conservation tenures cover a larger total area (29% of the total) than economic tenures (8% of the total).

Climate Change

The climate in British Columbia has changed over the last 50 years, with average air temperature becoming higher in many areas. The climate changes reported for British Columbia are consistent with broader trends in North America and the type of changes predicted by climate models for the region.

- With the exception of the North Coast, winters have become drier throughout most of the province.
- Sea surface temperature has risen along the entire coast, with the North Coast and the central Strait of Georgia showing the largest increases. Deep-water temperatures have also increased in inlets on the South Coast.
- With the exception of areas of the coast being pushed up due to geological processes, relative sea level has also risen along the coast.
- In BC, the largest source of greenhouse gas emissions comes from transportation, including commercial and private vehicles. From 1990 to 2002, greenhouse gas emissions in BC rose an average of 2.1% per year, which is less than the Canadian average of 2.8% annually.

For BC, the changing climate is expected to alter freshwater and hydroelectricity supply, affect productivity of freshwater and the ocean, change ecosystems, and increase risk of forest fires, pest outbreaks, and damage from extreme weather and flooding.

Industrial Contaminants

A wide range of contaminants originating from a variety of human activities are detectable in BC's coastal environment. Overall, environmental concentrations of PCBs, dioxins and furans, mercury, DDE, and other organochlorine pesticides have fallen as a direct result of regulatory controls on release of these substances to the environment instituted in the 1970s–1990s. Except at contaminated sites, concentrations of these substances in air, water, and the general environment are low.

- Dioxin and furan levels in pulp and paper mill effluents have dropped to non-detectable levels since 1990. Environmental monitoring shows a corresponding 95% decrease in dioxins and furans in the tissue of crabs and an 85% decrease in sediment contamination near mill outfalls.
- Concentrations of PCBs, dioxins, furans, and organochlorine pesticides in the eggs of great blue herons have dropped markedly since 1980; PCB concentrations in double-crested cormorant eggs show the same pattern of decrease.
- More than 46% of the area of shellfish beds closed to harvesting due to dioxin and furan contamination by 1995 has been reopened.
- Cleanup of coastal contaminated sites has been completed for half of the sites listed in the BC Contaminated Sites Registry; remediation is in progress for another 46% of the sites.
- Persistent contaminants, such as PCBs, dioxins and furans, already in the environment continue to circulate and accumulate in animals near the top of the food chain. PCBs remain the most toxicologically significant contaminants for BC killer whales and seals, and the contaminant levels reflect regional differences in contaminants in their diet. Southern resident killer whales are among the most contaminated marine mammals in the world.
- New industrial contaminants continue to emerge as issues, as exemplified by a new class of persistent contaminants—the PBDEs. They have become a focus of concern over the last decade as levels have been rising rapidly in the general environment and in the tissues of animals and people.

Despite controls, there are still continuous, low-level inputs of contaminants to the provincial environment. These come from local activities such as burning wood and waste, from soils and sediments that continue to release contaminants from past uses, and from accidents and spills. Some contaminants are transported through the atmosphere to BC from parts of the world where they are still in use.

Ecosystem Protection

As of January 2006, BC and Alberta had the largest proportion of land dedicated to protected areas in Canada—12.5% compared to 7.3% average for Canada (with recent announcements, the protected area for BC is 13.8%).

- Indicators developed to assess how effectively ecosystems in coastal BC are protected show that BC coastal terrestrial ecosystems are better represented than marine ecosystems. Along the coast, 11.7% of land is protected in 444 terrestrial protected areas that occupy 2.4 million hectares. Of the terrestrial ecosystems, the rugged and mountainous parts of the Central Coast are best represented.

- There are 130 marine protected areas, encompassing 240,000 hectares of marine habitat. Although this protects less than 0.5% of Canada's Pacific Ocean, it is nearly five time more area than existed in the 1970s. Most marine protection is in the zone less than 20 m deep, while the deep sea is the least represented area.
- Results of a risk assessment survey showed that experts considered that more than one-quarter of coastal protected areas were subject to high impacts from forestry, mining, and agriculture activities outside of the protected area.

A critical issue for protected areas is maintaining connections to other undisturbed habitats.

- As of January 2006, 46% of the land on the northern and central coast was ecologically intact (at least 2000 ha in size and 5 km away from roads), compared to the south coast, which had only 2.8% of the area ecologically intact.
- Roads are the largest source of habitat disturbance, particularly in the Georgia Basin where almost all of the land around protected areas has roads, isolating them from other intact areas.
- A preliminary analysis found that less than 25% of the continental shelf ecoregions remains undisturbed by human activity.

Biodiversity

The rugged BC coast, with its complex geography of deep fiords and countless islands, is home to animals that live nowhere else. It is one of the most biologically diverse areas in Canada. Of all the species in BC, two-thirds of the mammals and three-quarters of the freshwater fish live only in the coast region. One-quarter of all remaining coastal temperate rainforests in the world are found in BC.

- In 2005, 86 coastal BC species were listed as locally extinct, endangered, or threatened by the Committee on the Status of Endangered Wildlife in Canada. Of the 21 known species that have become extinct or extirpated from the province in recent history, 15 used to occur on the coast. One extirpated species, the sea otter, has been successfully reintroduced.
- Indicators show that the status of coastal vertebrates as a group has declined over the past 14 years; 4 new species were added to the red list, and there has been no improvement in status for most coastal vertebrates that were on the red list in 1992. Killer whales were added to the provincial and federal lists of species at risk after a period of population decline.
- Rare and sensitive ecosystems mapped on eastern Vancouver Island lost nearly 1400 ha (or 5%) over the past 10 years. At that rate, they could be gone in 20 years.

- At least 629 species of alien plants occur on the BC coast and about 65% of these have become widely established. Forty-one species of vertebrates have been intentionally or accidentally introduced to coastal BC. Alien microorganisms, insects and other invertebrates, including ballast water organisms, are not well documented, but are likely abundant.

Many of BC's ecosystems are relatively intact, particularly in the northern and central coast. Ecosystem loss is greatest in the South Coast where the human population is most concentrated. This area formerly contained some of the highest levels of biodiversity in the province, but it has been severely altered ecologically. It is likely that climate change will create additional pressure on ecosystems that are already stressed.

Fisheries

Overall, the indicators in this paper show that, although there are conservation concerns for some populations or stocks of fished species in BC, many appear to be doing well.

- An estimated 81% of the salmonid populations in BC (outside of Strait of Georgia) and the Yukon, are at no risk or have a low risk of extinction. Just over 13% of BC and Yukon populations were either extinct (2%) or at high risk of extinction.
- Stock assessment outlooks for 2004 classed 49% of managed salmon stocks in BC as stable, increasing, or well above target abundance, and about 13% of managed salmon stocks in the category of greatest concern.
- All assessed stocks of Lower Mainland steelhead trout were classified in 2005 as of conservation concern or extreme conservation concern.
- Other important commercial species, such as Pacific halibut, Pacific ocean perch, Pacific hake, geoduck clam, Dungeness crab, and herring, among others, have levels of abundance sufficient to sustain current harvest levels.
- Many inshore rockfish species are at low abundance levels or are experiencing poor recruitment, and 89 areas were closed to fishing at the time of writing.
- An international indicator of marine ecosystem structure, calculated for Pacific commercial fisheries, showed no trend in the trophic levels of fish caught since 1982. This means that there was no visible indication of changes in the structure of underlying marine ecosystems according to this measure, whether from fishing or other pressures.
- Estimates of the impact of regulatory and technological changes on reducing illegal and discarded catch in the salmon and groundfish fisheries showed that the regulations have had a positive effect.

Marine ecosystems are complex, and determining definitive causes for observed changes, whether positive or negative, is rarely straightforward. Whether the decline or low abundance of many of the species discussed in the indicators is related to overfishing, or to unfavourable ocean conditions perhaps related to global climate change is not known.

Population and Economic Activity

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Population and Economic Activity

INTRODUCTION

The coast of British Columbia is rich in natural resources from the sea and the land. The province derives a large proportion of its economic base from activities that take place in the coastal region, including coastal forestry, shipping, fishing, mining, recreation, and tourism. It is a gateway for commerce to other countries, with shipping ports that are vital to the Canadian economy. More than three-quarters of the population of the province lives on the coast.

Aboriginal peoples have relied on the resources of the land and sea for more than 10,000 years (possibly 40,000 years, e.g., Adler 2005). The rich environment of the northwest coast provided food, shelter, clothing, and raw material for implements and containers. The ocean provided transportation for the First Nations people who actively traded up and down the coast and into the Interior. They were part of a North Pacific maritime culture, with highly developed, densely populated societies living on the wealth of fish, shellfish, and other marine resources in the region (Glavin 2000).

The nature and magnitude of trade and economic activities changed dramatically with the arrival of Europeans in the 19th century. There was an abrupt drop in trading activity when smallpox and other diseases decimated the Aboriginal populations. In the early 1900s, economic activities increased with the introduction of industrial technology and development of transportation routes to eastern Canada and Europe via the transcontinental railways and the Panama Canal. Since World War II, the global demand for BC resources has driven a growing economy and stimulated a rapidly increasing population. Currently, an expanding service sector has widened the province's industrial and commercial base, but BC remains dependant on resource industries (Hallin 2001).

Today, the "marine highways" linking the ports of Vancouver, Victoria, and Prince Rupert to the rest of the world contribute to provincial, national, and global economies. In 2004 the Port of Vancouver handled 73 million metric tonnes of cargo and traded with more than 90 countries around the world (Port of Vancouver 2004).

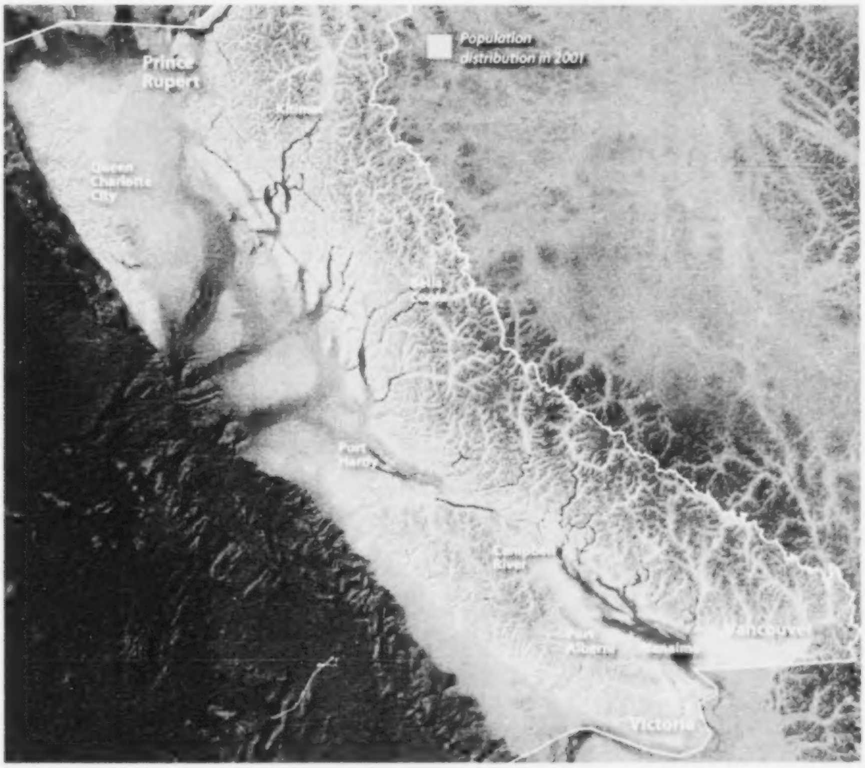
The Growing Population on the Coast

Estimates of the pre-European population of British Columbia range from 60,000 to 200,000 (Glavin 1996; Harris 1997). Diseases brought by Spanish and British explorers decimated the Aboriginal populations of BC and by the middle of the 19th century their numbers had dropped to a fraction of their former size. As the Aboriginal population declined, European settlement along the coast continued to grow. In 1851 the population of BC as a whole was 55,000; in 1951 it was more than one million, and by 2001 BC's population was 3.9 million (Statistics Canada 2005). In 2001, the Aboriginal population was 170,025 and accounted for 4.4% of BC's total population. The provincial population has been growing faster than Canada as a whole: from 1996 to 2001, BC's population increased by 4.9%, compared to a 4.0% increase for Canada (BC Stats 2003a).

Most (76%) of BC's population lives on the coast: in 1976 almost 2 million of the 2.5 million residents of the province lived in coastal BC. By 2001, just over 3 million people lived on the coast. The population of coastal BC is projected to increase by 29% by 2025. This is an increase of almost a million people in the coastal region alone.

Most coastal residents live in the Lower Mainland and southern and eastern parts of Vancouver Island, whereas the rest of the coast is sparsely populated (Figure 1). About 4% of the population on the coast is Aboriginal people; their distribution is similar to that of the general population, concentrated around Vancouver, Victoria, and Nanaimo.

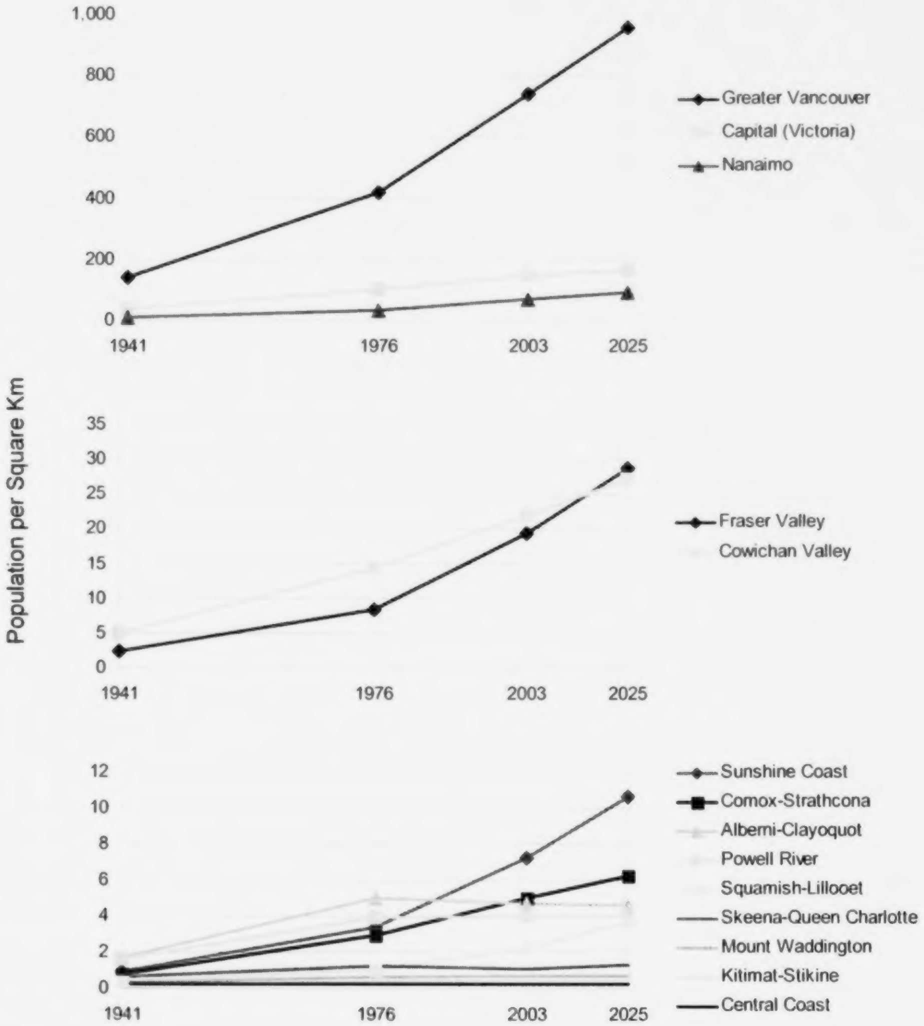
Figure 1. Population distribution in British Columbia, 2001. One dot equals 50 persons.



Source: BC Stats 2004a.

As the number of people living on the coast increases, pressure on the environment inevitably will increase whether through land use changes, increasing water demand, waste production, or emissions of pollutants. Population density projections, calculated as the number of people per square kilometre, show where the greatest pressures on land and marine areas are likely to be. Patterns of change in population density in regional districts, along with projected density in 2025, are shown in Figure 2.

Figure 2. Population density (people/km^2) in the coastal Regional Districts of British Columbia for 1941, 1976, and 2003, with projected population for 2025. Note the different scales on the graphs.



Source: BC Stats 2004b

The most rapid growth rates have occurred in the larger metropolitan areas of Vancouver and Victoria and along the east coast of Vancouver Island. Although growth rates in these areas have moderated substantially since the mid-1990s, they remain higher than most other regions of the province.

Not surprisingly, the Greater Vancouver Regional District (GVRD) has the highest population density. It has increased about five-fold between 1941 and 2003. The population density in this region is projected to continue increasing, but at a slower rate than in recent years. The Capital Regional District has the next highest density and is expected to continue increasing, but at a markedly slower rate than Greater Vancouver.

The Nanaimo Regional District has the third highest population density, with rapid growth between 1976 and 2003. The Fraser Valley and the Cowichan Valley are also fast growing areas, reflecting a transition from a mainly rural area to one that, at least in parts, is becoming quite urbanized. This change is also occurring to a lesser degree in the Sunshine Coast and Squamish-Lillooet regional districts; the increase in the latter area is due mainly to the recent rapid growth around Whistler.

Although population density on the south coast continues to increase, density in coastal districts north of Campbell River and Powell River has remained low. In two regions, Alberni-Clayoquot and Skeena-Queen Charlotte, density actually decreased somewhat between 1976 and 2003, probably because of the downturn in the forest industry in these communities. By 2025 projections show that population density for Alberni-Clayoquot is expected to drop slightly and Skeena-Queen Charlotte may increase slightly.

The population patterns reflect both the continual expansion of urban centres and a shift in the economic and industrial activity on the BC coast. Population declines in rural and remote areas are associated with the decline in relative importance of traditional labour intensive resource industries such as forestry and fisheries.

Impacts of a Growing Population on the Coastal Environment

The most obvious impact on the environment from the growing coastal population is the permanent loss of habitat to industrial and residential development, especially in the Georgia Basin. Forested land, wetlands, estuaries, and the riparian zones along streams, lakes, and seashores have all been disturbed or lost to provide housing, employment, recreation, and transportation for people living on the coast. Increasing use of urban and suburban land brings increasing development of transportation and utility corridors to move goods and people between urban centres and farther from the urban core. As development spreads out or "sprawls" in an unplanned manner beyond existing urban centres, it encroaches on natural habitats and agricultural lands. Urban sprawl also means that people travel longer distances from homes to work or shopping areas, leading to heavier reliance on roads and cars. The result is that natural land cover, which has a greater filtration capacity, is replaced by pavement (e.g., roads, parking lots) and other impervious surfaces, such as buildings. Consequently, the surrounding land becomes more highly erodable due to rapid surface runoff from impervious surfaces.

Another consequence of increasing population and density is the increase in air and water pollution and release of other contaminants from human activities. Both fresh and marine water quality are affected by the release of excess nutrients and contaminants into the environment from sewage, agricultural, and surface runoff, and vehicle and marine vessel traffic. The growing scale of sewage and solid waste disposal problems, as well as release of smog-forming chemicals and greenhouse gases, strains both local and global ecosystems.

Concern about the negative environmental and social impacts of urban and suburban sprawl has given rise to "smart growth" approaches to land-use planning and development. Smart growth is defined as land use and development practices that enhance the quality of life in communities, preserve the natural environment, and also save money over time (Curran and Leung 2000). Local governments are applying smart growth principles to regional growth strategies and official community plans. Smart growth strategies have been found to increase the liveability and economic vitality of developed areas, especially in larger municipalities (SmartGrowth BC 2004).

Paradoxically, declining populations in rural and remote communities also create pressure on the surrounding environment. Many communities are struggling with the loss of natural resource industries (e.g., logging, fishing) and are working toward diversifying their economy. The issues facing these communities in transition include job loss, shrinking tax base, school closures, loss of health services, deteriorating infrastructure, and less government funding

As a result these communities have a diminished capacity to manage environmental issues. For example, towns that are declining due to mill or mine closures may experience environmental impacts associated with site contamination (Fraser Basin Council 2004). Improper pesticide use and outdated sewage practices can degrade the water in small rural watersheds (Canadian Rural Partnership 2001).

Coastal Resource Industries: Backbone of the Economy

British Columbia's important natural resource-based industries, such as forestry, fishing, aquaculture, and mining, produce more than half the value of all BC exports (BC Stats 2006). Tourism is another economic activity that relies on healthy natural resources. Most of these economic activities have an impact on ecosystems, either temporarily (e.g., after logging a forest grows back, although the structure and function of the forested ecosystems may be altered) or permanently (e.g., surface mining and gravel pits permanently remove native vegetation and soils). These activities may also change ecosystems in ways we do not fully understand, especially in the marine environment. Even an activity such as ecotourism that aims to have low environmental impact can still put pressure on the environment (e.g., increasing human disturbance in sensitive habitats).

Forestry

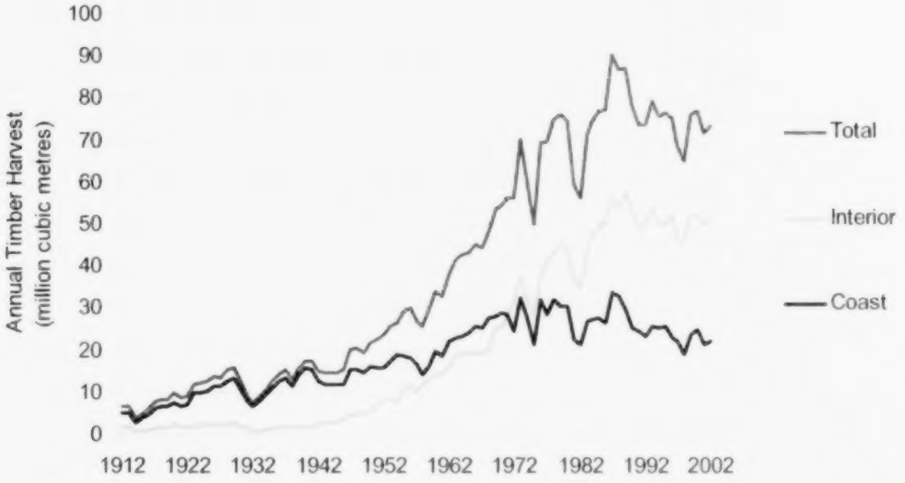
Industrial forestry began around the turn of the 20th century. From 1912 to the late 1980s, the annual timber harvest for the province increased tenfold (Figure 3). In 2004, the province's forestry and logging industry contributed $3.3 billion (in 1997 dollars) in value to the provincial economy (calculated as gross domestic product or GDP). The

GDP for paper and paperboard mills was an additional $1.5 billion (Lillian Hallin, BC Stats, pers. comm., 2005).

Although it remains the dominant industry in many communities, the logging and forest products industry has been undergoing tremendous changes. Due to its reliance on world markets, it is particularly susceptible to the economic climate in the rest of the world. Concerns among consumers about the environmental impacts of logging practices, competition from Europe and Asia, and changes in the demand for forest products have also had a major effect on BC's forest sector (Hallin 2001). Throughout the province, the forest industry has faced economic losses due to the U.S tariff on softwood lumber and increasing requirements to manage for environmental values. The latter includes managing for old growth and wildlife values under the Forest and Range Practices Act, 2004, and voluntary certification for sustainable forest management.

Although the total provincial harvest levelled off in the 1990s, harvesting on the coast has been in decline for decades for many reasons: closures of old sawmills and pulp mills that were inefficient, a decrease in accessible big trees for which the old mills were designed, and increasing costs of accessing timber higher up the mountains.

Figure 3. Annual timber harvest in British Columbia, 1912 to 2002.



Source: BC Ministry of Forests, harvest billing system (internal database).

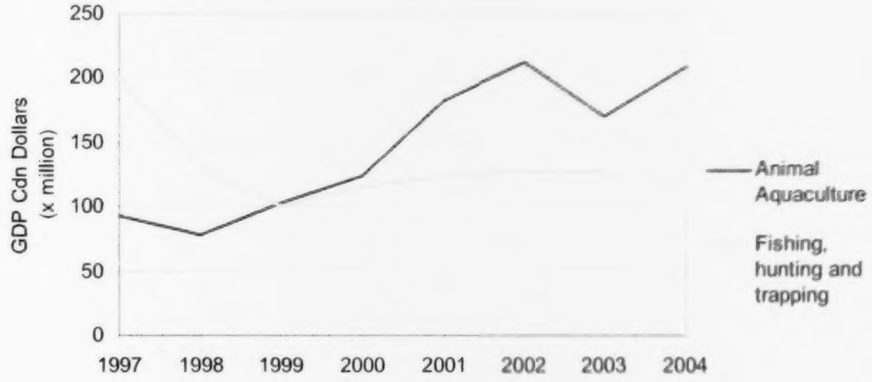
Fisheries and Aquaculture

Coastal First Nations people have fished in BC waters for many thousands of years and attach great cultural significance to the marine environment and its resources. Europeans have fished in BC since the 1800s, catching herring, salmon, halibut, and many other species of groundfish, pelagic fish, and invertebrates. First Nations people actively participate in commercial fisheries in addition to their food and ceremonial fisheries. Economically, the state of fisheries and marine ecosystems is an important issue for the many BC coastal communities that depend on fishing (see related Coast and Marine Environment project Paper: Fisheries).

Aquaculture also has a long history in British Columbia, beginning with the commercial cultivation of Pacific oysters in the 1920s. Finfish farming has developed more recently and together with shellfish farming is now a significant force within the fisheries and aquaculture sector.

The value of aquaculture has been increasing in recent years, and in 2004 the provincial GDP for aquaculture was $208 million, almost twice that of commercial fishing, hunting, and trapping combined at $115 million (Figure 4).

Figure 4. Trends in provincial GDP (in 1997 dollars) for aquaculture and fishing, hunting, and trapping in British Columbia.



Source: Lillian Hallin, BC Stats, pers. comm., 2005.

Note: Animal aquaculture includes shellfish and finfish farms. Fishing, hunting, and trapping includes freshwater and marine commercial fisheries, but most of the value for this category comes from marine fishing.

Tourism

In 2000 BC tourism generated $10 billion in revenues and provided full-time jobs for an estimated 130,000 people. This sector continues to grow at a rate of 4 to 5% annually (BCMSRM 2003a). More than half of all nature-based tourism businesses in BC are located on the coast and about 45% of these are marine-related (e.g., boating, fishing, scuba diving, charters, and lodges) (Tourism BC 2005).

- Cruise ships: In 2003, more than 400 cruise ships brought over a million visitors to the ports of Vancouver and Victoria (BREA 2004). Cruise-related spending totalled

$660 million and generated an estimated $1.2 billion in direct and indirect economic benefits, as well as over 10,000 full and part-time jobs.

- Recreational fishing: This is one of the highest revenue generators of all marine tourism on the coast, contributing an estimated $700 million annually to the regional economy (DFO 2003).
- Whale watching: In 2001, there were 38 whale watching companies operating 71 vessels around southern Vancouver Island (Marine Mammal Monitoring Project, 2002). The Haro Strait area alone brought in an estimated $12 million of direct revenues in 1999 (Lien 2001).
- Diving: In 2003, the industry was valued at $15 million (gross revenue) with 116 dive operators in BC serving over 24,000 divers (Tourism BC 2004).

Tourism and other nature-based recreational activities can have environmental impacts. For example, whale watching activities may be affecting whale feeding behaviour and communications; impacts accumulate from recreational boats (oil leaks, fuel spills, raw sewage, household wastes, toxic paint residues, air pollution from inefficient outboard engines, and disturbance to wildlife); and cruise ships can generate more waste than a small town (e.g., smoke emissions, sewage, bilge waste, solid waste, and hazardous waste from photo chemicals, dry cleaning, paint, and batteries).

Mining

British Columbia is an important producer and exporter of copper, gold, silver, lead, zinc, molybdenum, coal, and industrial minerals. In 2004 the GDP for mining in British Columbia (including oil and gas extraction) was estimated at $3.5 billion (in 1997 dollars; Lillian Hallin, BC Stats, pers. comm., 2005). Mining impacts include ecosystem and habitat loss, erosion, and discharge of contaminants (e.g., metal leaching and acid rock drainage).

The Network of Economic Activities on the Coast

Economic activities occur throughout the length and breadth of the coast on private and Crown lands. Economic development on Crown lands, which account for 95% of the provincial land area, is managed by the provincial government through tenure allocation. Tenures are leases and licences assigned to a defined parcel of land for a specific period. The most extensive land-based tenures issued by the province along the coast are forest licences, tree farm licences, and timber sale licences. In addition to tenures for land-based activities such as mining and timber harvesting, there are many tenures for activities in marine areas such as intertidal and nearshore seabeds (e.g., log handling and storage areas).

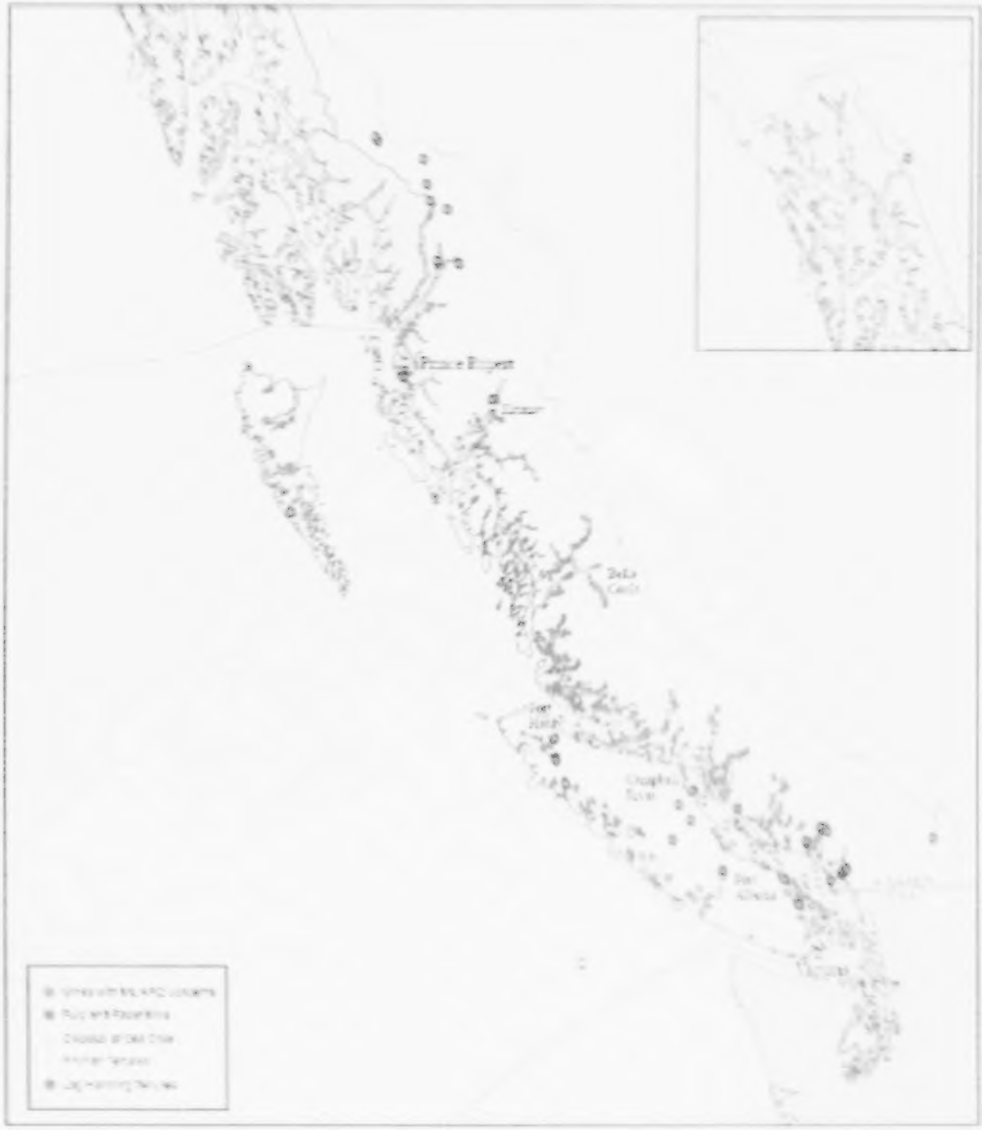
The environmental impacts of manufacturing, timber harvesting, mining, and other economic activities differ depending on the site. Impacts may be limited to just the developed footprint or may extend beyond the manufacturing plants or tenure boundaries through dispersal of pollutants by tides and currents and disturbance of sediments. Land-based industries, such as pulp mills and mines, discharge pollutants directly into the marine environment or into streams and rivers that carry pollutants to the marine environment.

Figure 5 shows the location of key sites for five types of economic activity and tenures that affect the marine environment. These are not the only sites for economic activities on the coast, but they are widely distributed activities associated with such key industries as logging, pulp and paper, finfish aquaculture, and mining.

- **Log handling and storage tenures.** Log handling sites account for most coastal tenures, but only parts of these sites are in use at one time. Impacts on the local environment come from dropping logs into shallow water, scouring benthic habitats, and smothering marine plants and other organisms with woody debris and surface runoff. Best management practices now guide log handling facilities to deeper water with rocky substrates and to areas without concentrations of sensitive plants such as eelgrass and kelp beds.
- **Pulp and paper mills.** Pulp mills have historically had major impacts on the local marine ecosystem, including releasing mercury in the early 1970s and discharging dioxins and furans until the early 1990s. Both problems have been dealt with through changes in technology to meet legislated pollution control requirements. Traces of past dioxins and furans remain, however, in sediments around mill sites and are still present in smokestack emissions (CCME 2001).
- **Finfish aquaculture tenures.** There are a large number of tenures, particularly along the middle and northern coast of Vancouver Island, but not all tenure locations, or all of the area in each tenure, are in use at the same time. Net pens are meant to be moved periodically to reduce the impact on the area below the pens. Impacts may include alterations to phytoplankton communities from increased nutrient loading, or elimination of certain bottom-dwelling organisms due to deposition of organic wastes. Another area of controversy, currently under study by Fisheries and Oceans Canada, is the impact of sea lice (a small, parasitic crustacean) on the health of wild pink salmon and whether this is related to net-pen aquaculture in the Broughton Archipelago.
- **Mines.** British Columbia has hundreds of both current and out-of-production mineral and metal mines. Figure 5 shows only those mines with environmental impacts due to metal leaching and acid rock drainage (caused when sulphide minerals are weathered and exposed to air and water). Most of the mines shown are out-of-production (BCMWLAP 2002). Before the BC Ministry of Energy and Mines will issue a permit, metal and coal mines must now predict the potential for metal leaching and acid rock drainage and have mitigation plans in place if necessary.
- **Disposal at sea sites.** Ocean dumping sites are primarily for disposal of dredged, excavated, and other uncontaminated materials, as well as fish waste and inert materials such as concrete, steel, vessels, or other structures. The Environment Canada Disposal at Sea program monitors disposal sites to ensure that the conditions

of the permit are met and that the marine environment has not been significantly affected.

Figure 5. Five types of economic activities and tenures on the British Columbia coast.


Prince Rupert
Bella Coola
Port Hardy
Campbell River
Port Alberni
Mines with ML/ARD concerns
Pulp and Paper Mills
Disposal at Sea Sites
Finfish Tenures
Log Handling Tenures

Sources: Log handling and finfish tenures and pulp mill locations were derived from the Crown Land Registry and provided by BCMSRM (now Integrated Land Management Bureau) in 2005. Mine data is from the Ministry of Energy and Mines Mineral Inventory File (MINFIL database). Disposal at Sea sites were provided by Environment Canada.

The following indicators show selected pressures from human activities on the coastal environment, as well as responses that address those pressures.

INDICATORS

1. Key Indicator: Rate of change of selected land uses in the Greater Vancouver Regional District, 1986 to 2002

This is an impact indicator. It was developed as one of several indicators addressing the impact of increasing population on the coast: it specifically reports on land use changes and impacts of "smart growth" strategies in the Vancouver area.

Changes in land use patterns show the pressures that expanding human population and economic activities are placing on the surrounding environment. Tracking the rate of change over time can help determine whether efforts to limit urban sprawl are effective. This indicator reports the results of an analysis of land use changes in the Greater Vancouver Regional District (GVRD) between 1986 and 2002 (BCMSRM 2004a).

Methodology and Data

In 2004/05, a pilot project was undertaken to map changes in land-use patterns in the GVRD using satellite imagery. The project was funded jointly by the provincial government, the Biodiversity Conservation Strategy for the Greater Vancouver Region initiative (partner project under the Georgia Basin Action Plan), Environment Canada, and Natural Resources Canada. The project was managed by the Business Solutions Branch of the Ministry of Sustainable Resource Management who retained Timberline Forest Inventory Consultants Ltd. and Geospatial International Inc. to perform the analyses.

This study examines changes over time in the characteristics of land use at a broad or regional level, as reflected in land cover visible in satellite imagery. The land use categories defined for this study were for provincial reporting and are not necessarily the same as categories used in local or regional planning initiatives or data (e.g., the Biodiversity Conservation Strategy for the Greater Vancouver Region, GVRD Land Use data). Although the analysis was based on a relatively coarse image scale, the methodology was consistent across time periods, and the study therefore shows overall trends in land-use patterns. Local planning departments in the GVRD have information on land use at a more detailed scale.

The type of land cover (defined as the composition and characteristics of land surface) results from a mixture of natural and human influences (Cihlar 2000). Land use, however, is characterized by the economic uses of land and people's relationships with the environment (Avery and Berlin 1992). For example, although land with trees on it could be classified as a land cover of "forest," from a land use perspective it might be classified as a "park." Similarly, immediately after logging, cut blocks no longer show a land cover of trees, but if they are replanted and remain in the forest inventory, they would retain a "forest" land use. This means that determining land use change from satellite photographs, which show land cover, is complex and requires cross-referencing with other data sources. The categories of land use derived for this study are described in Table 1.

Table 1. Categories of land use developed for the GVRD study area and used in this indicator.

Categories	Definition
Agriculture	Land-based agricultural activities undifferentiated as to crop (i.e., land is used as the producing medium).
Agriculture/Urban Mixtures	Areas where agriculture activities are intermixed with residential and other buildings with a density of 2 to 0.2 ha. Also includes rural residential at this housing density without agricultural activities.
Old Forest	Forest 140 years old or older and more than 6 m in height. Areas defined as Recently Logged and Selectively Logged land uses are excluded from this class.
Young Forest	Forest less than 140 years old and more than 6 m in height. Areas defined as Recently Logged and Selectively Logged land uses are excluded from this class.
Recently Logged	Timber harvesting within the past 20 years, or older if tree cover is less than 40% and less than 6 m in height.
Selectively Logged	Areas where the practice of selective logging can be clearly interpreted on the Landsat TM image and TRIM aerial photography.
Recreation*	Land used for private or public outdoor recreational purposes. Ski resorts and golf courses are included. This class does not include recreational areas within built-up portions of cities, towns, and villages, which are mapped as urban areas. This class includes waterfront cottage areas if they are at least 200 m wide.
Mining	Land used now (or in the past and remains unreclaimed) for the surface extraction of minerals or quarry materials.
Urban	All compact settlements including built-up areas of cities, towns, and villages, as well as isolated units away from settlements such as manufacturing plants, rail yards, and military camps. In most cases residential use will predominate in these areas. Open space, which forms an integral part of the urban agglomeration, e.g., parks, golf courses, etc., are included as urban.

Source: BCMSRM 2004a.

*Does not include parks; except for Stanley Park, parks were included as Urban.

Notes: The following land use types are not included in this study because there were no changes in any year: alpine, avalanche chutes, barren surfaces, burns, highway, glaciers and snow, fresh water, rangeland, river, transmission, and salt water.

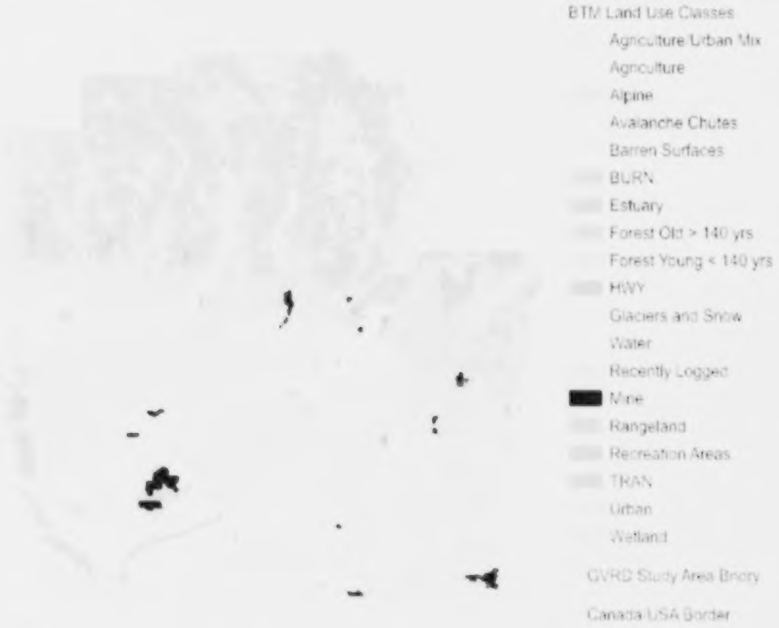
The study area covered a total of 375,456 ha, consisting of the GVRD area plus a 2-km buffer (except along the US border). The study included only areas above the high water mark as defined by the provincial Terrain Resource Information Management Program (TRIM).

Land-use maps at an overview level (baseline thematic mapping or BTM) and land-use change maps were produced for four time points (1986, 1993, 1998, and 2002). The land-use maps were produced primarily from Landsat satellite imagery, along with other sources of information, including existing land-use maps for some years. The land-use maps were digitized and the areas calculated and classified. Information sources that supported the work included digital orthophotographs, air photographs, and supplementary inventory datasets.

Overview land-use mapping (BTM) already existed for 1993 and 1998; therefore Landsat data were used to update and backcast these maps for the GVRD area to current BTM standards. A new land-use coverage was created to add 1986 and 2002 data to the BTM product for the GVRD area. The minimum size for a contiguous single land-use polygon for any one point in time was 10 ha. Where polygons had increased in size, it was possible to detect changes of as little as 2 ha, but only if they added to an existing polygon. Each polygon's attributes were compared with the underlying Landsat image attributes to determine if the land use had changed.

Figure 6 is a view of the most recent (2002) pattern of the 10 land use categories as defined in the study. Results for all years are shown in Table 2, which shows the net change in each category, for each period, and for the entire study (1986 to 2002). Figure 7 is a graphical display of the net change in area of each category over each time period.

Figure 6. Land use in the GVRD, 2002.


BTM Land Use Classes
Agriculture Urban Mix
Agriculture
Alpine
Avalanche Chutes
Barren Surfaces
BURN
Estuary
Forest Old > 140 yrs
Forest Young < 140 yrs
HWY
Glaciers and Snow
Water
Recently Logged
Mine
Rangeland
Recreation Areas
TRAN
Urban
Wetland
GVRD Study Area Bndry
Canada/USA Border

Source: BCMSRM 2004a.

Table 2. Change in land use in the GVRD, 1986 to 2002, and net change for the entire study period.

	Land use (ha)							
	1986	1993	Change 1986-1993	1998	Change 1993-1998	2002	Change 1998-2002	Net change[a] 1986-2002
Agriculture/urban mix[b]	16,511	16,511	0	17,430	919	17,393	–37	+882
Agriculture	31,728	31,684	–44	31,712	28	31,733	21	–7
Forest								–2996[c]
Old (≥140 yrs)	70,245	68,691	–1555	68,459	–231	68,436	–23	
Young (<140 yrs)	66,634	66,627	–6	66,772	145	67,399	627	
Recently logged	7,499	8,760	1261	6,530	–2230	5,806	–724	
Selective logged	559	559	0	0	–559	0	0	
Mines (gravel pits)	2,009	2,077	68	2,139	63	2,132	–7	+124
Recreation	707	707	0	1,182	475	1,178	–4	+479
Urban	93,660	93,936	276	95,761	1826	95,910	149	+2251

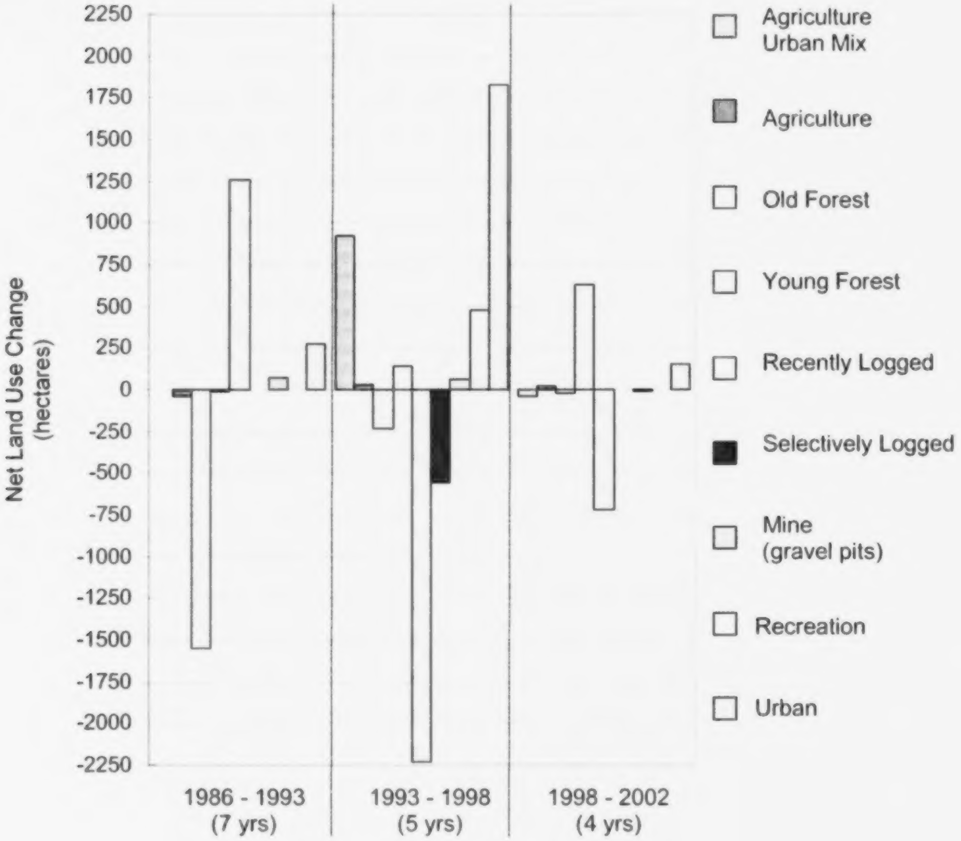
Source: BCMSRM 2004a.

[a] Net change is the sum of positive and negative changes in area, thus does not show whether a particular use may have gained area in one location while losing it in another location.

[b] Due to the relatively coarse mapping level, small changes, such as in density of housing, may not be detectable in this category.

[c] Figures for the four forest classes were combined to calculate the total net change in forestry land use. This takes into account the fact that some areas moved from "recently logged" to "young forest" (<140 yrs) and others moved from young to old forest (≥140 yrs) over the 16-year period.

Figure 7. Net change in land use (ha) in the GVRD, 1986-2003 by land cover and land use type.



Source: BCMSRM 2004a.

Table 3 shows details of how much land in a particular category in 1993 had been converted to other uses by 1998 and what those uses were. This period was illustrated because most of the land use changes between 1986 and 2002 occurred in the 1993 to 1998 period. Tables for other intervals show little change over the time period; for further information, see the complete report (BCMSRM 2004a).

Table 3. Detailed pattern of changes in land use categories in the GVRD between 1993 and 1998.

Land use in 1993	Changed to, by 1998	Area changed (ha)
Mixed agriculture	Urban	257
Agriculture	Recreation activities	179
	Urban	373
Forest		
Old forest (≥140 yrs)	Recently logged	249
Young forest (<140 yrs)	Agriculture/urban mix	608
	Agriculture	299
	Old forest (>140 yrs)	18
	Recently logged	267
	Mining	47
	Recreation activities	265
	Urban	1113
Recently logged	Agriculture/urban mix	8
	Young forest (<140 yrs)	2738
Selectively logged	Agriculture/urban mix	559
Mining	Agriculture	91
Recreation activities	Urban	68

Source: BCMSRM 2004a.

1986 to 1993: Relatively little net change in land uses took place in the GVRD during this period. Old forest area decreased 1555 ha (over 2% of the total) due to logging. Most of this area, however, remained in the forestry use category as reflected in the increased area in the recently logged category (1261 ha). Through the 1986–1993 period, forested areas appear to have been cycling through old forest, harvest, and re-establishment to young forest, so most harvesting did not result in conversion to urban or other uses (deforestation). Most of this old growth forestry activity was outside the urban core areas and about half occurred in the Regional District's water supply areas of the Capilano, Seymour, and Coquitlam watersheds. There were small losses of agricultural land to urban use in this period.

1993 to 1998: A rapid rate of urbanization of the region in the mid-1990s is shown by the higher rate of change to more urbanized land uses in this period. Detailed analysis (Table

3) of the land use conversions showed net losses of forests and agricultural land, mostly to urbanization. The urban land use category grew by 1826 ha, a much larger increase than in the preceding 7-year period or in the next 4-year period. During 1993–1998, 2332 ha of young forest were converted to other uses, most (1721 ha) to urban or mixed agriculture/urban use. This conversion is not evident from the net change figures for the period because it is masked by the large area that moved from the "recently logged" to "young forest."

All selectively logged lands recorded in 1986 were converted to mixed agricultural/urban land use by 1998. The agriculture/urban mix category increased by 919 ha (an increase of more than 5%), compared to no change in area during the previous period.

Another related land use change brought about by increasing population and consumer demand was the conversion of lands outside of urban use areas (agriculture and young forest) to recreational uses such as ski areas, golf courses, and large waterfront cottage areas. Recreational-use land increased by 67% (475 ha).

1998 to 2002: During this period there was a return to a lower rate of change in land use. The rate of conversion to urban use fell to one-tenth of the previous 5 years, with some of the new urban hectares coming from agriculture/urban mixed use land (i.e., from already urbanizing areas), and from young forest lands. The largest net change was a total of 850 ha that was re-established as young forest after appearing in the previous period as "recently logged."

A closer examination of deforestation—defined as land likely permanently lost from the forestry land base as a direct result of human activities—showed that 300 ha was deforested from 1986 to 1993; 2899 ha from 1993 to 1998; and only 121 ha from 1998 to 2002.

Interpretation

Overall, land use change accelerated during the 1993 to 1998 period, after which the rate of change dropped. These statistics show that most of the expanded urban area came from forest land (1113 ha) with conversion of agricultural land second (373 ha). Although the percentage increase in urban use area (about 2%) since 1986, and in agriculture/urban mix use area (about 5%), may seem small compared to the size of the region, these changes took place over a relatively short period.

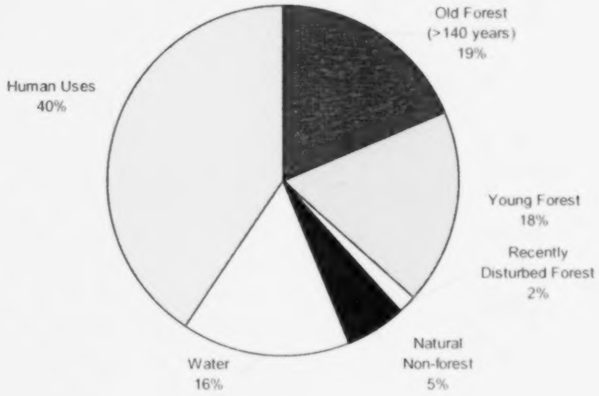
Given the continued increase in population—more than 25% during a similar time period (1991–2001) for the GVRD (BC Stats 2004b)—these trends appear to confirm the success of urban containment or "smart growth" strategies within the Greater Vancouver Regional District. A 2002 study by Northwest Environment Watch (2002) and SmartGrowth BC compared urban sprawl for Greater Vancouver (including most municipalities in the GVRD) and Greater Seattle and reported that, despite a very high growth rate, Vancouver's policies had resulted in 62% of its population living in compact communities (30 persons per hectare or more) in 2001. Five years earlier, 57% of the Vancouver population lived in compact communities. In comparison, 25% of Seattle residents lived in compact communities in 2000. This means that Seattle residents take up more land per capita, with greater impacts on regional ecology, than Vancouver residents.

In the Lower Mainland, policies at the regional level, such as the Greater Vancouver Regional District's Livable Region Strategic Plan, coupled with municipal land-use policies and the provincial Agricultural Land Reserve (ALR) appear to have restrained suburban sprawl and slowed the loss of rural land and open space over the last 30 years (Northwest Environment Watch 2002). Population and density, however, continue to increase on the BC coast, particularly in the areas north and east of Greater Vancouver (BC Stats 2004b).

STATUS OF FORESTS IN THE GREATER VANCOUVER REGIONAL DISTRICT (GVRD)

In contrast to the coast of BC as a whole, which has only 2% of the land area converted to human uses, such as urban, agriculture, mining, and recreation, almost half of the GVRD area is occupied by such uses (Malcolm Gray, Business Solutions Br., BCMSRM, pers. comm. 2004). However, standing forest, including both young and old forest, still covers about 40% of the GVRD. Only 2% has been logged within the past 20 years and that area is currently regrowing as forest (BCMSRM 2004a).

Figure 8: Proportion of land cover and land use in the GVRD in 2002.



Source: BCMSRM 2004a.

Supplementary Information: Loss of Wetlands in the GVRD

As part of the larger study described above, a more detailed study looked at the loss of wetlands. Wetlands provide critical habitat for fish, birds, and other wildlife; they also perform vital ecosystem functions, including:

- absorbing and filtering sediments, pollutants, and excess nutrients;
- recharging groundwater, maintaining stream flows, controlling runoff, and storing flood waters;
- reducing erosion and stabilizing shorelines; and
- helping regulate atmospheric gases and climate cycles (BCMOE 2005).

Because most wetlands in the study area are small, it was found that reviewing orthophotographs in areas where land cover change was identified from multi-date Landsat imagery was an accurate method for identifying and mapping wetland loss. All available polygon datasets were used to stratify land cover into "potential wetlands" for 1986, 1998, and 2002. An aggregation, or super-set, of wetlands was created from the following datasets: BTM land use, TRIM base mapping (Geographic Data BC 2001), Vegetation Resources Inventory (BCMOF 1999), Township of Langley land-use inventory, Canadian Wildlife Service inventory of wetlands lost between 1989 and 1999, and the Fraser River Estuary Management Program habitat inventories (2002/03).

After the composite wetlands inventory was prepared, lost wetlands were identified through both the Canadian Wildlife Service wetlands inventory, Landsat change detection methods and interpretation of orthophotographs for the two periods, 1986–1998 and 1998–2002.

Using this methodology, the total wetland area reported for the GVRD in 1986 was 33,155 ha. In 2002, a total of 32,000 ha remained, resulting in a calculated loss of 1115 ha since 1986. To put these figures in context, it is important to realize that this does not take into account the amount of wetlands lost before 1986, nor does it reflect the fragmentation and degradation of many existing wetlands. It is estimated that 85% of the wetlands in the lower Fraser Valley (from Vancouver to Hope) have been lost to human activities since the early 1800s when much of Richmond and Delta was wetland (Boyle et al. 1997). Most of this change in wetlands occurred before 1932.

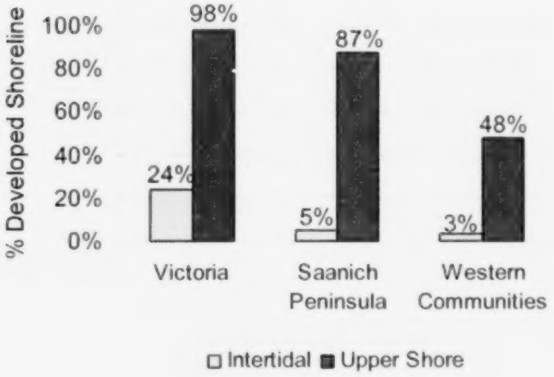
Supplementary Information: Shoreline Development in the Capital Regional District

Intertidal and upper shore zones are particularly vulnerable to development because people are attracted by the views and easy access to beaches and the ocean. In 2001, the BC Nearshore Habitat Loss Working Group reported that 23% (60 km) of the estuarine and other nearshore habitat in the Georgia Basin had been urbanized and the shorelines altered by dykes, seawalls, docks, and other uses (BC Nearshore Habitat Loss Working Group 2001).

In 2000, for a state of environment report, the Capital Regional District (CRD) analyzed data on the length of natural shoreline and the length of developed shoreline (CRD 2000). Data for the intertidal zone were from 1993 and for the upper shore zone from 1997. The upper shore was defined as 50 m horizontally from the high tide mark. Development included marinas, docks, breakwaters, and dredging in intertidal zones, and pavement, buildings, non-native vegetation, and cleared land in upper shore zones. The study area included the Western Communities (View Royal, Colwood, Langford, Metchosin, Sooke, Highlands, and Juan de Fuca electoral area), the Saanich Peninsula (Sidney, North Saanich, and Central Saanich), and the core of Victoria (Victoria, Saanich, Esquimalt, and Oak Bay).

More than 375 km of shoreline exist in the CRD's study area (which excluded the Gulf Islands). In total, 68% of upper shore zones had some type of development, and 8% of intertidal zones had been developed (Figure 9). The more urbanized core of the CRD study area had the highest proportion of shoreline development (98% upper shore, 24% intertidal). Along the Saanich Peninsula, 87% of upper shore lands were developed and 5% of the intertidal, and in the Western Communities, 48% of upper shore lands were developed and only 3% of the intertidal (CRD 2000).

Figure 9. Proportion of shoreline developed in the Capital Regional District.



Source: CRD 2000.

2. Key Indicator: Proportion of BC coastal population served by municipal wastewater treatment

This is a response indicator. It addresses the question: What is being done about the impact of sewage on the environment? The indicator shows the management response to the problem of sewage disposal in British Columbia.

One of the major impacts people have on the environment is the discharge of raw or treated sewage, directly or indirectly, into marine or estuarine environments. By volume, municipal sewage and combined sewer overflows are one of the largest point sources of pollution to Canadian waters. Depending on the level of treatment, sewage effluents carry nutrients and other substances such as chlorine, motor oil, paint thinner, antifreeze, pesticide residues, pharmaceuticals, and solvents into receiving waters; raw sewage also carries the risk of human disease bacteria into the environment. These inputs can cause eutrophication and oxygen depletion, toxicity, and other impacts on fish and wildlife, and can create food safety (see next indicator) and other health and aesthetic issues for people. The impact of sewage discharge on the marine environment depends on the degree of treatment to remove nutrients and other contaminants as well as on the volume of discharge.

The primary purpose of wastewater treatment is to protect human health and to reduce stress on the receiving environment. Before being discharged to the environment, sewage is treated to remove some impurities and to reduce the biological oxygen demand (BOD) and total suspended solids (TSS). The level of treatment used by a municipality is an indicator of the amount of pollutants being discharged to the environment. It also depends on the sensitivity of the receiving environment (e.g., amount of salinity, flow, available dilution, sensitive species), because a higher treatment level is required if the receiving environment does not have sufficient purifying ability.

Preliminary and primary treatment filter out solid material, secondary treatment removes much more fecal material, and tertiary treatment goes beyond this to remove target substances such as contaminants. With each increase in the level of treatment, the BOD and TSS are further reduced. Tertiary treatments increasingly tend to be used where there are particularly sensitive ecosystems, where there are health concerns, or where water is to be reused.

Methodology and Data

Wastewater data for the Georgia Basin were obtained from Environment Canada (2005a).

Data for other coastal communities came from the online Environment Canada Municipal Use Database (MUD; Environment Canada 2005b). The MUD database contains water and wastewater data reported to Environment Canada by municipalities having populations of more than 1000 people. The MUD database reports the populations served by preliminary, primary, secondary, and tertiary treatment systems, as well as those with no sewage treatment. Reporting is voluntary and the number of municipalities reporting can vary from year to year. Inconsistencies in the MUD data were such that it was not possible to use the most recent data reported for 2002.

Municipalities included as part of the coastal region were selected on the basis of regional districts. This method resulted in some omissions (e.g., Smithers and Telkwa, which drain into the coastal waters via the Bulkley and Skeena rivers, but are not in the study region for the Coast and Marine Environment project).

The MUD database does not show the reasons for changes in the figures reported by municipalities from year to year. Reductions in one type of treatment may be a result of increasing treatment capacity or treatment upgrades, but they may also be a result of a change in population or a shift of the population from outside to inside areas with sewers. Table 4 shows the coastal populations served by different sewage treatments.

Table 4. Coastal population served by different sewage treatments.

		Treatment (% of population)				
Location	Population with sewers	None	Preliminary	Primary	Secondary	Tertiary
Georgia Basin						
1983	1,564,787	3.5	8.0	80.2	8.3	0.0
1989	1,828,476	2.1	7.7	76.7	13.3	0.1
1994	2,132,293	1.1	7.5	75.6	15.5	0.3
1999	2,365,802	0.3	8.5	36.2	54.5	0.5
Other coastal communities[a]						
1983	78,218	29.4	0.0	2.5	62.3	5.8
1989	75,473	30.9	0.0	0.0	62.5	6.6
1994	73,954	33.9	0.0	0.0	66.1	0.0[b]
1999	75,307	24.6	0.0	0.0	75.4	0.0

Sources: Environment Canada 2005b; Georgia Basin data from Environment Canada 2005a.

[a] Waste stabilization ponds are reported by MUD separately, but are here included with secondary treatment because they are considered to achieve an equivalent level of treatment.

[b] Port Hardy reported tertiary treatment to 1989, then secondary treatment in 1994; thus the 1983 and 1989 figures may be erroneous.

Interpretation

Given the voluntary and possibly inconsistent nature of sewage treatment reporting, only large changes are likely to indicate real trends. After modest increases (2–4%) in secondary sewage treatment from 1983 to 1994, there was a large increase (about 40%) in secondary treatment (and corresponding decrease in primary treatment) in 1999 for the Georgia Basin. This change was due to the upgrade of the Annacis Island Wastewater Treatment Plant from primary to secondary treatment. The plant serves approximately 850,000 people in 14 GVRD communities before discharging to the Fraser River. By 1999, more than half the Georgia Basin population and three-quarters of the population in other reporting communities had secondary treatment.

By 1999, virtually all of the population on sewers in the Georgia Basin had some form of treatment. About 8–9% of the Georgia Basin population is served by only preliminary treatment, mainly in the core of the Capital Regional District (Esquimalt, Saanich, Oak Bay, and Victoria) on Vancouver Island. By 1999 about a quarter of the population in municipalities outside of the Georgia Basin had no treatment (i.e., they have septic systems) and three-quarters of the population had secondary treatment of the discharged sewage. About 0.05% of the population on the coast was served by tertiary treatment.

In comparison, in 1999 across Canada, 97% of the reporting municipal population served by sewage systems had some form of sewage treatment—19% primary, 38% secondary, and 40% tertiary. Although a higher overall percentage are on sewer systems (99%) on the BC coast, the level of tertiary treatment (0.5%) in this region was considerably below the national average (Environment Canada 2004b,c).

Although more advanced forms of treatment reduce contaminants and thus the impact of sewage to receiving waters, they do not remove toxic substances and they still leave disposal problems, including the disposal of sewage sludge. Sludge disposal methods include disposal at sea, in landfills, disposal as a fertilizer on agricultural land, use as infill material on disturbed lands, and incineration. All these disposal methods have associated risks to the environment.

Supplementary Information: Volume of Sewage Released into the BC Marine Environment

The highest volume of sewage discharge is in the Georgia Basin (Table 5). Volume has been increasing due to population growth and the addition of new areas to municipal sewage systems (i.e., converted from septic systems). In the Georgia Basin, 1983 to 1999, the daily volume of sewage discharged to the environment increased by more than 60%. From other coastal communities the volume more than doubled, reflecting a large increase in the proportion of the population converting from septic systems to sewers (see Indicator 2: The Proportion of BC Coastal Population Served by Municipal Wastewater Treatment).

Table 5. Treated sewage discharges reported by municipalities in coastal British Columbia, 1983 to1999.

Location	Number of municipalities reporting	Total treated sewage (kilolitres/day)
Georgia Basin		
1983	50	823,251
1989	54	1,176,157
1994	55	1,154,522
1999	60	1,333,844
Other coastal communities*		
1983	14	26,294
1989	14	35,578
1994	15	35,205
1999	14	56,804

Sources: Georgia Basin data: Environment Canada 2005a; Other coastal communities: Environment Canada 2005b.

* Includes communities of more than 1000: Port Alberni, Alberni-Clayoquot, Tofino, Ucluelet, Gold River, Tahsis, Port McNeill, Port Alice, Port Hardy, Prince Rupert, Masset, Kitimat, Kitimat-Stikine, Terrace, and Stewart.

3. Secondary Indicator: Trends in shellfish closures due to sewage contamination

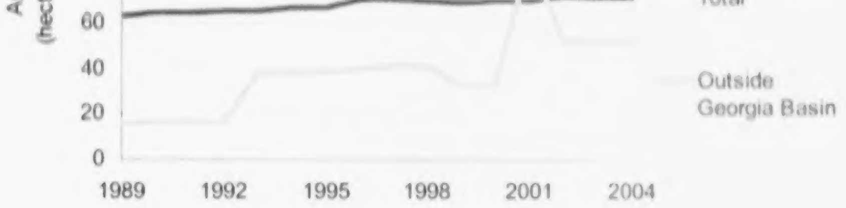
This is an impact indicator. It addresses the question: What are the impacts of human activities on coastal ecosystems? The area of shellfish beds closed due to fecal contamination is used as a surrogate for the area of impact from sewage and other human sources.

Fecal coliform bacteria indicate the presence of human or animal wastes and the possible presence of other disease-causing organisms. Areas of shellfish beds are closed when they are found to be contaminated with fecal coliform bacteria. Marine contamination from these bacteria comes from a variety of sources, including urban runoff, sewage discharge, and agricultural drainage. Sporadic outbreaks of contamination also come from wildlife sources.

Methodology and Data

Data were obtained from Environment Canada, Ecosystem Information Section, and Fisheries and Oceans Canada. Environment Canada has been monitoring the sanitary quality of shellfish-growing waters on BC's southern coast since the early 1970s. Surveys include 2600 ha of coastal waters used for shellfish aquaculture as well as about 750,000 ha used for wild shellfish harvesting. Areas are closed to harvesting if fecal coliform counts exceed specified standards. (Note that the data do not include closures for paralytic shellfish poisoning.)

Figure 10. Trends in the area of shellfish beds closed to harvesting in British Columbia.



Source: Environment Canada 2005c.

Interpretation

The increase in area of shellfish closures is primarily a result of increasing population and associated sewage discharges. The data show that closures of shellfish harvesting areas have increased since the 1970s. Before 1976, less than 60,000 ha of shellfish growing area was under closure orders. The area had increased to about 80,000 ha in 1990, and to 124,000 ha in 2003–2004, more than doubling the closure area since 1976.

Outside of the Georgia Basin, the shellfish harvest area under closure increased more than threefold (by 36,000 ha) from 1989 to 2004. The increase was partly a result of expanded monitoring programs as well as growing development along shorelines (Environment Canada 2005c). The spike in 2001 reflects a 46,000 ha temporary seasonal closure in Clayoquot and Barkley sounds believed to be caused by contamination from wildlife sources. Wildlife fecal contamination originating from terrestrial sources that are flushed into the ocean during periods of high rainfall typically occur for short periods and soon return to normal background levels (DFO 2001).

Georgia Basin locations represented 58% (72,000 ha) of the area closed to shellfish harvesting in 2004. The closure area within the Georgia Basin has remained stable partly because an extensive area was already closed, particularly in the Burrard Inlet, Fraser River estuary, and Boundary Bay areas. Remedial programs have removed only small areas from the sanitary closure restrictions.

In some locations (such as in the Queen Charlotte Islands), new closures are a result of an increase in the extent of monitoring and assessment of shellfish areas. In other instances, reductions in area are due to water quality restoration initiatives and the reassessment of temporary closures.

Inadequate sewage treatment is only one cause of elevated levels of fecal coliform bacteria. Often multiple and complex sources are responsible, particularly in the lower Georgia Basin; sources include non-point sources such as poorly placed or maintained septic tanks outside of the sewered areas, agricultural and urban runoff, and discharge from marine vessels. Overall for the BC coast, such multiple sources are thought to account for the largest proportion of closures (59%), followed by agricultural and urban drainage (13%), hinterland drainage (11%), sewage outfalls (10%), and marine vessels (7%) (Environment Canada 2005c).

4. Key Indicator: Trends in density of marine traffic

This is a pressure indicator. It addresses the question: What are the impacts from human activity along the BC coast?

The increase in marine traffic is a result of expanding regional and oceanic trade, the growing tourism industry (especially cruise ships), and increasing recreational boating activities. Marine traffic affects marine ecosystems when it is a source of disturbance and pollutants, whether from sewage discharge or bilge cleaning, or from accidents, oil spills, and other pollution incidents. It can disturb wildlife, particularly marine mammals and breeding, wintering, and moulting birds. Underwater noise from motors and activity may alter the behaviour of marine mammals, and heavy use of marine parks, ecological zones, and recreation areas degrades sites and disturbs breeding birds and intertidal habitats. Marine vessel motors also emit pollutants that contribute to regional and local air pollution.

International shipping traffic increases the risk of introducing exotic and invasive species carried on ship hulls and in ballast water. More than 3000 species of animals and plants are estimated to be transported around the world daily in ballast water (NRC 1996).

Methodology and Data

The Coast Guard's Marine Communications and Traffic Services (MCTS) provides Vessel Traffic Services (VTS) to vessels operating in Canadian waters. All ships must obtain VTS clearance before beginning a voyage from a Canadian location or before entering Canadian waters. Since 1999, there have been five VTS zones: Vancouver, Victoria, Comox, Prince Rupert, and Tofino.

MCTS monitors ship traffic using radio contact, radar, and in an increasing number of cases, satellite tracking. Ship identification and route information is collected, including type, size, position, direction, and speed.

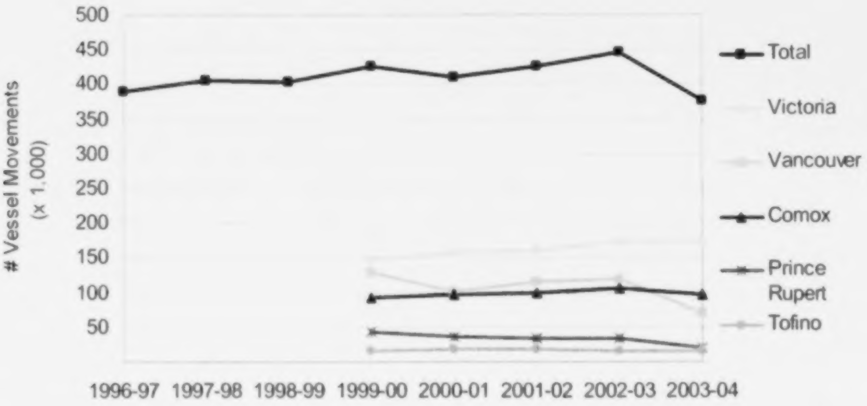
An annual summary of the number of ship movements on the BC coast was acquired from the MCTS survey of vessels (*www.pacific.ccg-gcc.gc.ca/mcts-sctm/vesseltrafficservices_e.htm*). Patrick O'Hara (UVIC/CWS/DFO Birds Oiled at Sea visiting scientist) analyzed the data for this indicator. The survey included ships over 20 m in length, and ships engaged in towing or pushing any vessel or object more than 20 m (other than fishing gear) that had a combined length of more than 45 m.

The survey did not include vessels towing or pushing inside a log booming ground, pleasure yachts less than 30 m, or fishing vessels less than 24 m and 150 tons gross, which are not required to report to VTS.

The dataset covers Canada's Pacific offshore waters west of the Queen Charlotte Islands and Vancouver Island and the inside waters, including the Victoria area from Beechey Head to Haro Strait (but not Juan de Fuca Strait, which is the responsibility of the US Coast Guard). Because not all vessels are included, these data represent a minimum estimate (J. Dufour, MCTS, Canadian Coast Guard, pers. comm., 2005).

Figure 11 displays only vessel movements for the current VTS zone configuration (1999 to 2004). The definition of "vessel movement" is standardized across all VTS zones. Vessel movement includes any vessels entering, exiting, or travelling through a VTS Zone.

Figure 11. Vessel movements by Vessel Traffic Service (VTS) zone in BC, 1999 to 2004, and total marine vessel movements in BC, 1996 to 2004.

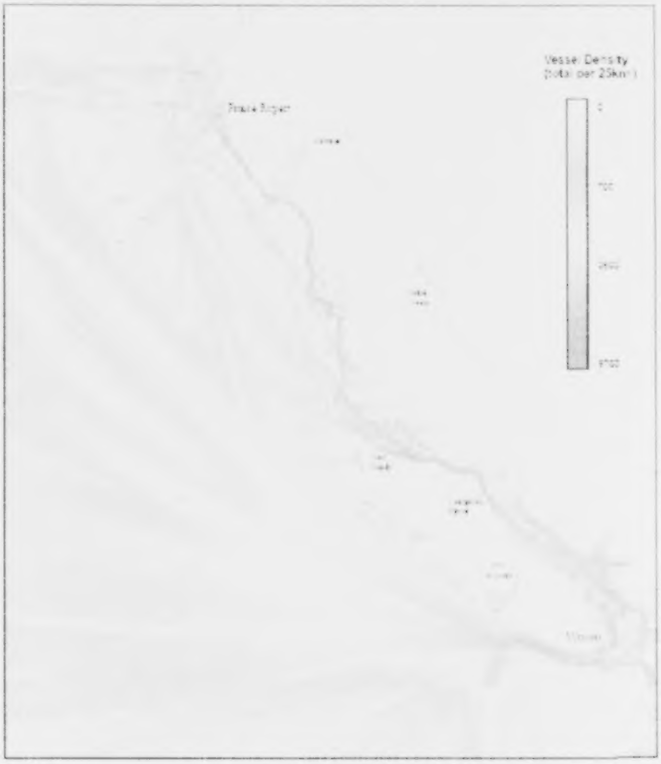


Source: MCTS, Canadian Coast Guard, 1997–2004.

Notes: [a]Values for 2003/04 for Vancouver may be low due to a tugboat strike at the Port of Vancouver. [b]Before 1999/2000 the Vancouver VTS zone included Victoria and Comox. For clarity, data before that year were not included in this graph for the separate VTS zones.

Shipping patterns off the BC coast remained relatively constant during the survey years, so ship movements in 2003 are shown in Figure 12 to illustrate general patterns on the BC coast. For the map, observations were reduced to one uniquely identifiable ship observation per 5 × 5 km cell in a GIS grid. Shipping intensity was calculated by summarizing the total number for each cell of identifiable ship observations per ship category, for data pooled within each season (Summer, 1 May to 30 September; Winter, 1 October to 30 April).

Figure 12: Marine traffic vessel density (per 25 km^2) along the coast of British Columbia in 2003.



Source: MCTS, Canadian Coast Guard.

Changes in annual vessel movements between 1999 and 2004 differed by VTS zone (Figure 11). Vessel movements increased slightly for Victoria and Comox and decreased for Prince Rupert and Vancouver. The traffic in the Tofino VTS zone has remained relatively constant over the period. The marked decrease at Vancouver in 2003-04 was likely due, at least in part, to a 10-day tugboat strike at Deltaport, the largest of three Port of Vancouver container terminals. The strike suspended movement of tugboats (the largest component of vessel movements within the Port of Vancouver) and the ships that they would have serviced. Thus, the figures for 2003/04 do not represent normal traffic volumes for Vancouver.

Average annual vessel movements for the different types of vessels (Table 6) indicate that passenger vessels accounted for an average of 56% and tugs accounted for 29% of the marine traffic on the coast.

Table 6. Annual vessel movements by vessel type from 1996/97 to 2003/04 for the coast of BC.

Vessel type	Vessel description	Average number of vessels/year	Percent of total
Tankers	Carrying liquid cargo, primarily oil	2,739	<1
Chemical	Tankers carrying liquid chemicals, including petroleum and natural gas	1,278	<1
Cargo	Bulk cargoes such as cars, grain, ore, etc.	29,253	7
Tugs	Towing or propelling barges	117,319	29
Fishing	Catching, processing, or transporting fish under the Fisheries Act	11,078	3
Passenger	Includes ferries and cruise ships	229,095	56
Other	All vessels not in other categories	19,541	5
Total		410,301	100

Source: MCTS, Canadian Coast Guard.

Interpretation

The impact of marine traffic depends on the type of vessels, where they travel, and the time of year. Victoria, Vancouver, and Juan de Fuca Strait VTS zones have the highest traffic volumes (Figure 12). In this area, with the province's highest population, high marine traffic volumes are one more of many stresses on marine ecosystems. This region is also critical habitat for the southern resident population of killer whales. They range in this area throughout the year, but especially during salmon migrations. There is concern that noise from heavy marine traffic in the Georgia and Juan de Fuca straits may be interfering with the killer whales' ability to locate prey and communicate with each other, but this has not been assessed (Killer Whale Recovery Team 2005). Fortunately, ship collisions with whales are rare on the BC coast, but increasing marine traffic in shipping lanes that cross whale migration and feeding areas increases the risk of collision (Environment Canada 2004d).

Three other shipping routes—the Inside Passage, Hecate Strait, and the west coasts of Vancouver Island and Queen Charlotte Islands—have considerable activity, but are not as heavily used as the southern routes. With the planned expansion of the port at Prince Rupert (Industry Canada 2005), traffic volume along the north coast can be expected to increase in future. An example of potential impact of marine vessels is the tugboat traffic that passes by the Scott Islands in the summer, at a time when the islands are home to more than two million breeding seabirds. This is a concern because Canada's National Aerial Surveillance Program, which regularly conducts marine oil pollution patrols, has found that tugs may be the source of many of the small-scale oil spills off the coast of BC (P. O'Hara, DFO, pers. comm., 2005). Seabirds congregate both on the open ocean and adjacent to their breeding colonies, so they are particularly susceptible to major and minor spill events anywhere in the Scott Islands area (Environment Canada 2004a).

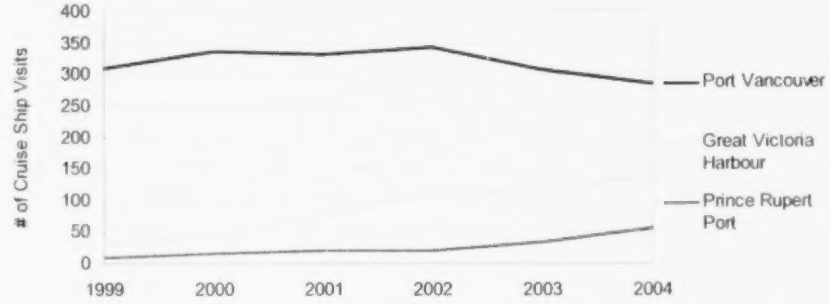
The impact of shipping, in terms of number and type of ships, can also vary in some routes with the seasons. The MCTS annual summary data show overall shipping traffic is greater in summer than in winter and varies according to vessel type (P. O'Hara, UVic, CWS, DFO, pers. comm., 2005). The distribution of bulk carrier, cargo, and tanker traffic does not change much seasonally. Fishing vessel traffic, however, is very seasonal because it depends on fishery openings. Cruise ship traffic is seasonal, with the heaviest traffic during the summer both through the Inside Passage and outside Vancouver Island, north through Hecate Strait and Queen Charlotte Sound.

SUPPLEMENTARY INFORMATION: CRUISING ON THE COAST

The cruise ship industry has played an increasingly important role in BC's economy during the last two decades. In 1995, 283 cruise ships visited at the three main ports of call in BC (Vancouver, Victoria, and Prince Rupert). From 1999 to 2004 (see Figure 13), there was a high of 462 visits in 2002, which dropped somewhat to 381 in 2004. Over the same time, however, total passenger visits doubled, showing that the size and capacity of visiting ships has increased. The number of ports of call within BC is increasing and the cruise ship industry is planning to initiate BC-only cruises that will also include smaller ports along the BC coast (BC Stats 2003b).

Cruise ships carry an average of 2,000 crew and passengers and generate more waste and sewage than a small town (Nowlan and Kwan 2001). Little documentation exists on cruise ship impacts in British Columbia. Violations reported in Alaskan waters may also occur in BC's inland waters because the same ships travel between Seattle and Alaska. In recent years, the cruise ship industry has been developing new environmental policies and waste treatment technologies (minimization, re-use, and recycling) that go beyond international standards (Dobson et al. 2002). It is not known, however, how many cruise ships currently plying BC waters meet these more rigorous levels of waste management.

Figure 13: Cruise ship visits to three BC ports, 1999 to 2004.



Source: Lillian Hallin, BC Stats, pers. comm., 2005.

5. Secondary Indicator: Marine pollution reports by vessel traffic service zone

This is a pressure indicator. It addresses the question: How much does marine traffic contribute to pollution in the marine environment?

World wide, oil and other chemical spills from ships have caused major devastation of marine wildlife and coastal ecosystems. Smaller spills from ports, shipping facilities, and marinas and emissions of air pollutants from ships adds to the burden on the coastal environment.

Methodology and Data

In Canada, it is a federal offence to accidentally or wilfully discharge oil, garbage, sewage (depending on location), or other pollutants into Canadian waters. Polluters are required under law to report all oil spills to the Canadian Coast Guard.

The Marine Communication and Traffic Services (MCTS) compiles pollution reports on pollution originating from oil handling facilities or vessels using the VTS system (described in Indicator 4). Pollution discharges are reported to MCTS from a variety of sources, but most pollution reports are recorded as a result of a vessel incident (i.e., vessels in difficulty) that resulted in pollution. In addition, pollution from such sources as bilge pumping and spills at docks may be observed and reported by Transport Canada aircraft surveillance, floatplane pilots, or individuals on shore. Figure 14 shows the number of pollution incident reports by VTS zone in BC from 1999 to 2004.

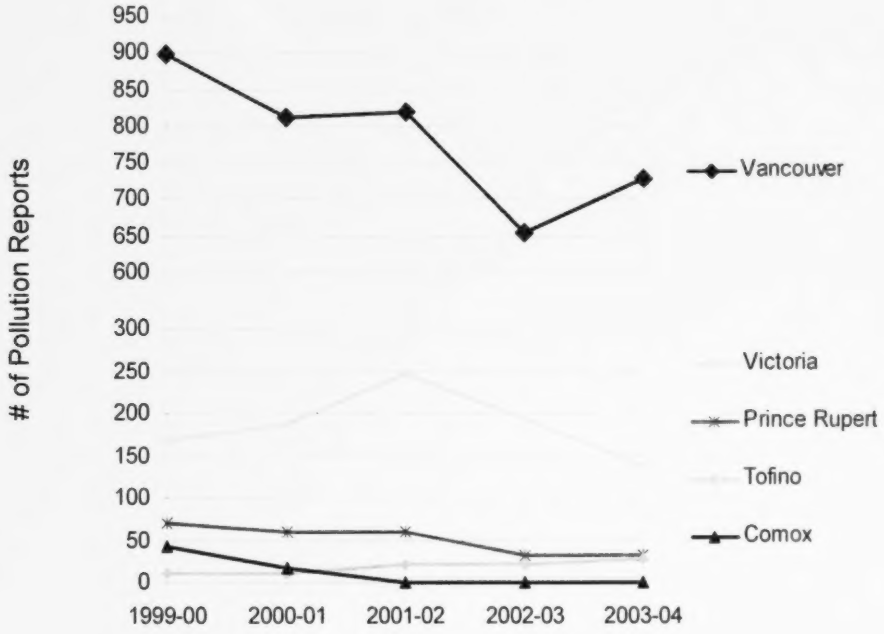
Limited data on reported marine spills were also obtained from the website of the BC Provincial Emergency Program (PEP 2005). PEP compiles reports of ocean-based (as well as inland) dangerous goods incidents from smaller commercial and recreational vessels. Approximately 95% of these incident reports involved oil spills (Stafford Reid, Ministry of Environment, pers. comm., 2005), because oil is more visible than other types of pollutants. PEP does not collect this information systematically because it is not always included in the MCTS pollution reports. Although there has been a slight decrease in ocean spills reported to PEP over the period 1989–2004, the number of incidents has remained at about 900 spills per year since the mid-1990s. There were 734 incidents in 2004/05, and about half were in the Vancouver region.

The total number of pollution reports ranged from almost 1200 in 1999/2000 to about 900 in 2002/03. Because pollution events are detected by chance, not all occurrences will have been reported. These data therefore represent minimum estimates of actual events. Since 1999, the Vancouver VTS zone accounted for approximately 75% of the marine pollution reports.

Note that data on the quantity of oil and other materials spilled (as opposed to the number of incidents reported in this indicator) are not currently available. The Pacific States/BC

Oil Spill Task Force established a Spill and Incident Data Collection Project in 1997 to standardize data collection, but figures are not yet available for BC.

Figure 14: Pollution incident reports per year from shipping by VTS zone, 1999–2004.



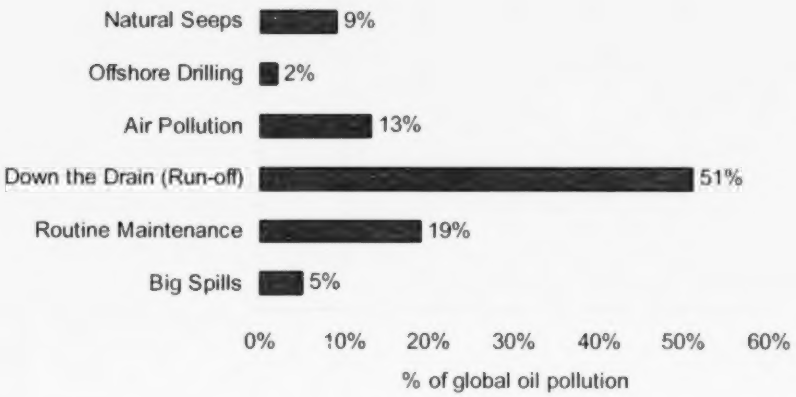
Source: MCTS, Canadian Coast Guard.

Interpretation

About half (52%) of the nation's reported spills occur on the BC coast, which is where half of all vessel movements in Canada occur (DFO 2004). Chronic spills are less visible than major spills such as the 1989 Exxon Valdez oil spill in Prince William Sound, Alaska, but they have persistent, cumulative impacts on marine organisms. Each year in the waters of Atlantic Canada, an estimated 300,000 seabirds are killed as a result of chronic oil pollution. Estimates are not available for the Pacific coast, but the National Aerial Surveillance Program has found a higher rate of oil spill observations off the west coast (calculated per flight kilometre) than off the east coast of Canada between 1997–2001 (DFO 2004), which means the impacts may be as serious as on the Atlantic coast. Data from the Beached Bird Survey (Bird Studies Canada 2004) attribute some seabird mortality to oiling in a few areas such as along the west coast of Vancouver Island, where up to half of the dead birds found were oiled (Ken Morgan, CWS, pers. comm., 2005).

Other major sources of marine oil pollution include routine ship maintenance (such as bilge cleaning) and land-based urban and industrial runoff entering storm drains and streams. Natural oil seeps (from the ocean bottom and eroding sedimentary rocks) account for as much oil pollution as offshore drilling and big spills combined. Information about sources of marine oil pollution is not available for coastal BC, but the sources and proportions are likely similar to the global situation (S. Reid, BC Ministry of Environment, pers. comm., 2005) as shown in Figure 15.

Figure 15. Global sources of marine oil pollution.



Source: Adapted from Smithsonian Institution 1995.

MARINE TRAFFIC AS A SOURCE OF AIR POLLUTION

Marine vessels are a major source of air polluting emissions in the Greater Vancouver airshed (GVRD 2003). The amount of emissions from ships is forecast to increase over the next 20 years (Table 7) due to sustained growth in freight movement through the Port of Vancouver and the Fraser River Port. The relative contribution of marine vessels also becomes higher as emissions from on-road motor vehicles decrease due to stringent new fuel and engine standards. According to the GVRD study, by 2010 marine vessels will exceed on-road motor vehicles as the largest source of air pollutants contributing to smog in the region. The GVRD is developing a strategy to reduce air emissions from marine vessels as part of the region's Air Quality Management Plan.

Table 8: Proportion of air emissions attributed to marine vessels in the GVRD in 2000 and forecast for 2025.

Pollutant	2000	2025
Sulphur oxides	61%	72%
Nitrogen oxides	25%	46%
Diesel particulate matter	38%	60%

Source: GVRD 2003.

6. Key Indicator: Economic and conservation tenures in the intertidal areas of BC estuaries

This is both a pressure indicator, showing the footprint of economic activities in estuaries, and a response indicator, showing conservation tenures in estuaries for habitat protection. It addresses the question: What is the extent of economic activities on estuarine habitats? What has been done to protect estuarine habitats?

Estuaries in BC account for less than 3% of the province's coastline, but these productive and diverse habitats are vitally important to many species. For example, it is estimated that 80% of all coastal wildlife use estuaries (Kelsey 1999). Estuaries are home to small fish such as sticklebacks, sculpins, and eulachon; invertebrates such as worms, clams, and crabs; and plants, such as sedges, saltgrass, and eelgrass. These species are food for the scores of waterbirds and shorebirds that use the estuaries. Estuaries are also essential habitat for salmon from the juvenile stage to migrating adults.

In BC, the intertidal area is owned primarily by the Crown. Activities permitted on Crown land are formalized by allocating tenures (leases, licences, and reserves) for a defined parcel of land for a specific period of time. Tenures in the intertidal and nearshore seabed include docks, intertidal shellfish aquaculture, nearshore finfish aquaculture, and floating fishing lodges. Conservation tenures are held by conservation and government agencies to protect areas with important ecological values.

This indicator shows the potential for impacts from economic activities in estuaries, but does not quantify those impacts or differentiate between tenure types. The intensity of activities within an existing tenure can change over time without changing either the size or type of tenure. Therefore, the cumulative impact of multiple activities within the economic tenure footprint is not known.

Methodology and Data

Estuary area

In 2004 the Canadian Wildlife Service of Environment Canada and Ducks Unlimited Canada identified and mapped 442 of the larger estuaries on the BC coast for the Pacific Estuary Conservation Program (PECP; Ryder et al. 2003). Mapped estuaries were those where the coastline intersected rivers that were either: fourth-order and higher as identified by the 1:50,000 BC Watershed Atlas, or 20 m or wider as identified by the 1:20,000 TRIM basemaps.

The survey captured all of the estuaries that met these criteria, but was not meant to be a comprehensive census of all estuaries in the province.

Intertidal features were captured as polygons for each estuary according to standardized mapping criteria, using existing provincial TRIM basemaps and Canadian Hydrographic Service (CHS) marine charts. Intertidal polygon features, such as delta, island, marsh, and CHS-charted intertidal area, were included. The total intertidal area for each estuary was derived from these polygons. The total intertidal area for all mapped estuaries was calculated to arrive at an estimate of total area of estuaries across the BC coast.

Because the original data sources (listed in Table 8) varied in scale and quality, the intertidal area calculated for each estuary is approximate. To achieve a more accurate estimate of intertidal area would require site visits and a scale of mapping beyond the scope of this project.

Table 8. Sources of data used to map the estuaries and identify economic and conservation tenures.

Data source	Yr.	Agency	Data location
Watershed Atlas	1996	BC Ministry of Environment, Lands, and Parks, Fisheries Division	*www.bcfisheries.gov.bc.ca/fishinv/basemaps-technotes.html*
Terrain Resource Information Management Program (TRIM)	1996	BC Ministry of Sustainable Resource Management	*http://srmwww.gov.bc.ca/bmgs/trim*
Digital Ocean electronic charts	2002	Fisheries and Oceans Canada, Canadian Hydrographic Service	*www.charts.gc.ca/pub/en*
Tantalis GATOR	2005	BC Ministry of Sustainable Resource Management	*https://tantalis.clrs.gov.bc.ca*
Digital datafiles and metadata	2004	Pacific Estuary Conservation Program: estuaries of BC mapping project	Canadian Wildlife Service, Pacific Wildlife Research Centre, Delta, BC

Tenure Area

In 2004, land tenure data were compiled for the intertidal areas of 440 of the 442 estuaries originally identified and mapped by PECP. Tenure information was not available in digital format for two of the province's largest estuaries, the Fraser River and Serpentine/Nicomekl River (Boundary Bay); they were therefore not included in this analysis. Tenure data are stored in the provincial cadastral database, Tantalis GATOR, which was the source of most of the data for this indicator. Only tenures in the intertidal areas of estuaries were mapped. Where tenures also included subtidal and upland areas, those portions of tenures were excluded from this analysis. Where the data sources showed an overlap of tenure polygons (due to differences in scale, quality, and age of the original data), problems were reviewed case-by-case, and the most appropriate source was used.

Based on the Tantalis GATOR "purpose" and "sub-purpose" labels listed in Table 9, tenures were assigned to one of two categories: economic tenures or conservation area tenures. The proportion of the intertidal area not under economic or conservation tenures was classified as "no designation."

Table 9. Purpose and sub-purpose labels in the provincial cadastral database, Tantalis, that were used to categorize economic and conservation tenures.

Economic interest tenures*	Conservation tenures
Agriculture	Environment protection/ Conservation
Aquaculture	Ecological reserve
Commercial	Fish and wildlife management
Commercial recreation	Protected area strategy
Community	Provincial park**
Energy production	
First Nations	
Industrial	
Institutional	
Miscellaneous land use	
Quarrying	
Residential	
Transportation	
Utility	
Waterpower	
Use, recreation, enjoyment of the public /Recreation reserve	
Forest Management Research	
Boat haven	
Fishery facility	
Rights-of-way**	

*Activities where conservation is not the primary purpose.

**Designations used in previous database that could not be assigned to more specific categories used in Tantalis at the time of conversion in 1998.

The number and area of economic tenures was totalled to arrive at the potential "footprint" of human activities on estuarine intertidal habitats across coastal BC (Table 10). ("Footprint" is used to mean the total area occupied by a tenure or collection of tenures.) Not all economic tenures are currently active; thus each tenure does not necessarily represent a current loss or alteration of habitat. Also, some economic tenures overlap. To eliminate double-counting of overlapping tenures, only the portion of a tenure within the intertidal area were identified and only the external boundaries was used.

Conservation tenures for estuary intertidal areas were also taken from the Tantalis GATOR database (Table 10). Other cadastral databases (i.e., Integrated Cadastral Initiative and local government databases) were also used to identify conservation agency holdings that were not in Tantalis GATOR. These conservation tenures are owned by Ducks Unlimited Canada, The Nature Trust of British Columbia, The Nature

Conservancy of Canada, Canadian Wildlife Service of Environment Canada (National Wildlife Areas), Parks Canada (National Parks), and BC Ministry of Environment (Provincial Parks, Ecological Reserves, and Wildlife Management Areas).

Although tenure data were not summarized for the Fraser River or the Serpentine/Nicomekl (Boundary Bay) River estuaries, these two estuaries generally have significant amounts of conservation tenures, and fewer economic tenures in the intertidal area.

The study found that, of the 440 estuaries:

- 164 (38%) estuaries had economic tenures present within the intertidal area, and 123 (28%) estuaries had conservation tenures.
- Economic tenures covered 8% of the total intertidal area of the 440 estuaries, and conservation tenures covered 29%.
- 30% of the estuaries with economic tenures had tenures that occupied 10–40% of the intertidal area; 16% of estuaries had tenures covering most or all (75–100%) of the intertidal area.
- 67% of the estuaries with conservation tenures had tenures that occupied most or all (75–100%) of the intertidal area.

There were differences between estuaries within the Georgia Basin and those estuaries outside the Georgia Basin:

- Of the 67 estuaries within the Georgia Basin, 39 (58%) had economic tenures and 30 (45%) had conservation tenures.

Of 373 estuaries outside the Georgia Basin, 125 (34%) had economic tenures and 93 (25%) had conservation tenures.

Table10. Status of economic interest tenures and conservation tenures in 440* estuaries in BC, by ecoregion.

	Number of estuaries (% of total)			Intertidal area (ha) (% of total)			
Ecoregions[a]	Total	With economic tenures	With conserv-ation tenures	Total	With economic tenures	With conservation tenures	With no designation (no tenures)
Coastal Gap	140	37 (26%)	31 (22%)	15,949.6	886.8 (6%)	4,132.5 (26%)	10,930.3 (68%)
Eastern Vancouver Island	33	23 (70%)	15 (45%)	4,603.6	824.4 (18%)	954.8 (21%)	2,824.4 (61%)
Lower Mainland	9[b]	5 (56%)	2 (22%)	653.6	26.6 (4%)	298.7 (46%)	328.3 (50%)
Northern Coastal Mountains	13	4 (31%)	2 (15%)	746.5	163.6 (22%)	131.9 (18%)	451 (60%)
Pacific Ranges	73	41 (56%)	17 (23%)	5,437.3	275.6 (5%)	1,683.9 (31%)	3,477.8 (64%)
Queen Charlotte Lowlands	15	3 (20%)	9 (60%)	2,393.0	165.7 (7%)	1290.7 (54%)	936.6 (39%)
Queen Charlotte Ranges	32	7 (22%)	4 (13%)	826.3	92.6 (11%)	37.8 (5%)	695.9 (84%)
Hecate Continental Shelf	1	0 (0%)	0 (0%)	0.1	0.0 (0%)	0.0 (0%)	0.1 (100%)
Western Vancouver Island	124	44 (35%)	43 (35%)	4,359.7	364.8 (8%)	1,542.7 (35%)	2,452.2 (57%)
Total	440	164 (38%)	123 (28%)	34,969.7	2,800.1 (8%)	1,0073 (29%)	22,096.6 (63%)
Inside Georgia Basin[c]	67	39 (58%)	30 (45%)	5,768.7	876.4 (15%)	1,397.8 (24%)	3,494.5 (61%)
Outside Georgia Basin	373	125 (34%)	93 (25%)	29,201	1,923.7 (7%)	8675.2 (30%)	1,8602.1 (64%)

[a] BCMELP 1996.

[b] This number excludes the Fraser River and Serpentine/Nicomekl River, which were not evaluated.

[c] The Georgia Basin includes all or part of the following ecoregions (number of estuaries within Georgia Basin in parentheses): Eastern Vancouver Island (26); Lower Mainland (9); Pacific Ranges (21); Western Vancouver Island (11). Total: 67.

Interpretation

More than a third (38%) of the mapped estuaries had some type of economic tenure allocated in the intertidal area. These tenures ranged in size from small to large portions of the intertidal area. Not surprisingly, more (58%) estuaries in the highly populated Georgia Basin had economic tenures than in other parts of the coast.

Although fewer estuaries (28%) had conservation tenures than had economic tenures, the total conservation area was more than three times the area under economic tenures. Where conservation tenures exist, they usually occupy a large proportion of the intertidal area. Distribution of conservation areas is uneven, however, and many estuaries have no conservation tenures. Most conservation tenures are concentrated in a few locations: Cape Scott Park, Brooks Peninsula Park, Strathcona Park, Fjordland Recreation Area, Pacific Rim National Park Reserve, and others. As with economic tenures, Georgia Basin estuaries had proportionately more conservation tenures than other areas of the coast. However, the proportion was still less than half (45%), which may be a concern given the highly productive marine ecosystems in the region (Mackas and Fulton 1989) and pressure from the high population density in the region.

Conservation tenures in estuaries provide varying levels of protection, depending on the activities permitted within their boundaries. Some have high levels of protection and restriction on activities, whereas others have few restrictions. Recreational activities, such as boating, fishing, and tourism pursuits that are permitted in some conservation areas may disturb coastal species and estuary habitats. For example, Burton et al. (2002) found that sustained disturbance reduced the local habitat quality for waterbirds and the carrying capacity of estuaries.

Over half of the total estuary intertidal area had no designation. Although these areas currently do not have economic tenures, they remain vulnerable to future development. Many of the areas have important environmental values that should be assessed as part of estuary conservation planning.

7. Secondary Indicator: Impact of nutrient loads from marine finfish farms in BC

This is a pressure indicator. By examining one measurable aspect of potential impact, it partly addresses the question: What is the impact of finfish aquaculture on marine ecosystems? This indicator calculates the annual input of nutrients to the marine environment from finfish aquaculture on the BC coast.

Tenures for finfish aquaculture (mainly Atlantic salmon) are concentrated along the central coast of BC and the outer coast of Vancouver Island. The fish are reared in floating net pens or cages in the water. Earlier research has shown that impacts from organic waste are generally limited to the benthic environment within several hundred metres of net pens (Gowen and Ezzi 1991; Brooks and Mahnken 2003). Recently, however, research has shown that impacts of increased nutrient addition from re-suspended organic waste particles, coupled with dissolved organic wastes, may have broader impacts. The effects range from eutrophication (when increased nutrients lead to excessive plant growth and depletion of oxygen in the water) to effects on the marine food web at distances farther from farm sites (Hargrave 2003; Strain 2005; Strain and Hargrave 2005). Such broad-scale changes are very difficult to assess, but the potential cumulative pressure from nutrient loads on the marine environment can be estimated from nutrient budgets obtained from fish farming data.

Methodology and Data

Under the BC Finfish Aquaculture Waste Control Regulation (BC Regulation 256/2002), the finfish aquaculture industry is required to report the amount (dry weight) and type of feed used for the previous calendar year. Data for this indicator came from the annual feed data that are submitted electronically to the Ministry of Environment. This regulation has been in effect only since September 2002; therefore, only 2003 and 2004 data were available for analysis.

For greatest accuracy, calculations of nutrient load should be based on the amount of feed used, the nutrient and energy content of the feed, feed wastage rates, and nutrient excretion/retention rates in Atlantic salmon. Many variables influence the values of these parameters, including fish health, water temperature, fish age and size, fish species, production levels, growth rates, feeding techniques, etc. However, because production levels and growth rates are considered proprietary information belonging to the aquaculture companies, these data were not available. Other variables, such as nutrient excretion/retention rates, are generally too expensive and difficult to measure to justify continuous or widespread sampling. Therefore, calculations for this indicator used actual feed data along with published values and common assumptions used in modelling nutrient loads from finfish aquaculture (e.g., Cho and Bureau 1998; Henderson et al. 2001; Cromey et al. 2002; Stucchi et al. 2005). The calculations used a nutritional modelling approach based on the digestibility of organic carbon and excretion and retention of dietary nitrogen and phosphorus in farmed salmon.

Feed Wastage

The issue of defining the amount of waste feed (FW) that is not consumed by farmed fish is a major source of uncertainty in quantifying the overall nutrient loading of finfish aquaculture sites. Although recent estimates of this value derived through mass balance modelling approaches (Strain and Hargrave 2005) are around 14–17%, industry and other methods of calculation indicate that loss rates are significantly less. Brooks and Mahnken (2003) in their review paper indicate that present day feed wastage rates are 5% or less. Other estimates of feed wastage (Table 11) provide a broad range of values, highlighting this uncertainty.

The uncertainty in estimates of feed wastage have led to recommendations for further research (Chamberlain et al. 2005) and are the subject of ongoing research by Fisheries and Oceans Canada. To accommodate the uncertainty in these estimates, we included calculations for nutrient loads based on both low (5%) and high (15%) values for the amount of waste feed (FW) (Table 13). Total nutrient loads are likely to fall within the range of these calculations on the BC coast.

Table 11. Estimates of feed waste produced by marine salmon farm operations.

Waste feed (% of total feed used)	Source
< 5%	Gillibrand et al. 2002
1-5%	Pearson and Black 2001; Beveridge et al. 1991
2-5%	Cromey et al. 2002
3-17%	EAO 1997
4-11%	Findlay and Watling 1994
14-17%	Strain and Hargrave 2005
Up to 20%	Gowen et al. 1989

Nutrient Content of Feed

Most recent studies indicate that the nutrient content of salmon feed has stabilized, with current levels of nitrogen and phosphorus near optimum levels for digestibility and the nutrient requirements of the fish (Hardy and Gatlin 2002). Data reflecting average total carbon, nitrogen, and phosphorous content as found by Petersen et al. (2005) and D. Higgs (Higgs et al., unpub. data, DFO-UBC Centre for Aquaculture and Environmental Research) were used in this indicator because they are the most recent figures available and are estimates for the high-energy grower diets used in the BC salmon farming industry (Table 12).

Table 12. Carbon, nitrogen, and phosphorus content of fish feed (expressed as a percentage of the total dry weight of the feed) as reported in the literature.

Nutrient	% of dry weight of feed	Source
Carbon		
	45%	Silvert 1994; Dudley et al. 2000; Findlay and Watling 1994
	44%	Gillibrand et al. 2002; Gowen and Bradbury 1987
	48.8-55.8%	Petersen et al. 2005
	[51.9%]	**Used in indicator** (Higgs et al. unpub. data)
Nitrogen		
	6.1-8.5%	Winsby et al. 1996
	6-7%	EAO 1997
	6.7%	Cho and Bureau 1998
	6-8%	Silvert 1994
	6.3-8.7%	Petersen et al. 2005
	6.5%	Brooks and Mahnken 2003
	7.19% ± 0.87	Naylor et al. 1999
	7.2%	Gillibrand et al. 2002; Enell and Ackefors 1992
	7.7%	Gowen and Bradbury 1987
	[6.57%]	**Used in indicator** (Higgs et al. 2006)
Phosphorus		
	0.7-1%	EAO 1997
	0.9%	Enell and Ackefors 1992
	0.9-1.1%	Hardy and Gatlin 2002
	0.9-2%	Winsby et al. 1996
	1%	Silvert 1994; Cho and Bureau 1998; Brooks and Mahnken 2003
	1.06-1.61%	Petersen et al. 2005
	1.15% ± 0.28	Naylor et al. 1999
	1.2%	Gowen and Ezzi 1992
	[1.27%]	**Used in indicator** (average of Petersen et al. 2005)

Nutrient Retention/Excretion

Carbon is excreted both in feces (as particulate waste) and from the gills (as dissolved CO_2 and bicarbonate). Only the particulate fraction was used in calculating carbon load for the indicator because the amounts of dissolved waste added are insignificant compared to the huge carbonate-buffering system of the ocean (EAO 1997). Nitrogen and phosphorus are also excreted as both particulate and dissolved wastes, and calculations for these nutrients include both fractions. See Table 13 for nutrient retention and excretion rate calculations and total annual loads of organic carbon, nitrogen, and phosphorus.

Table 13. Estimated outputs of organic carbon, nitrogen, and phosphorus from BC salmon aquaculture farms in 2003 and 2004.

	Output (tonnes)	
Parameter	2003 (96 sites)	2004 (98 sites)
Total feed (TF)	88,860	99,725
Fish produced (FP) [a]	80,782	90,659
Feed waste (FW)		
low (5%)	4,443	4,986
high (15%)	13,329	14,959
Feed ingested (FI) [b]	75,531	84,766
Organic carbon (OC) output		
-waste feed (OC_{FW}) [c]		
low (5%)	2,306	2,588
high (15%)	6,918	7,764
-fish (OC_F) [d]		
low (5%)	4,048	4,543
high (15%)	3,622	4,065
Total annual load	6,354-10,540	7,131-11,829
Nitrogen output		
-waste feed (N_{FW}) [e]		
low (5%)	292	328
high (15%)	876	983
-fish (N_F) [f]		
low (5%)	3,050	3,423
high (15%)	2,729	3,063
Total annual load	3,342-3,605	3,751-4,046
Phosphorus output		
-waste feed (P_{FW}) [g]		
low (5%)	56	63
high (15%)	169	190
-fish (P_F) [h]		
low (5%)	708	794
high (15%)	633	710
Total annual load	764-802	857-900

[a] Assumed a feed-to-gain ratio of 1.1 kg feed per kg fish produced (BC Salmon Farmers Association 2005)

[b] FI = TF–FW.

[c] OC_{FW} = FW × 51.9% (organic carbon 51.9% in high-energy extruded diet used in salmon farms; Higgs et al. unpub. data, DFO-UBC Centre for Aquaculture and Environmental Research).

[d] OC_F = (FI × 51.9%) × 9.24% (9.24% indigestible organic carbon in high-energy extruded salmon diet used in BC; Higgs et al. unpub. data, DFO-UBC Centre for Aquaculture and Environmental Research).

[e] N_{FW} = (FW × 6.57%) (6.57% nitrogen in grower diet used in BC salmon farms; Petersen et al. 2005.

[f] $N_F = (FI \times 0.0657) - (45\% \text{ of } FI \times 0.0657)$ (45% is the amount of ingested dietary protein (nitrogen) deposited or retained in farmed BC salmon (Higgs et al. 2006). N_F reflects both fecal and metabolic nitrogen losses.

[g] $P_{FW} = FW \times 0.0127$ (high-energy extruded diets used in BC salmon farms contain about 1.27% total phosphorus; Petersen et al. 2005).

[h] $P_F = (FI \times 0.0127) - (34\% \text{ of } FI \times 0.0127)$ (average of 34% retained dietary phosphorus in farmed Norwegian Atlantic salmon fed high-energy diet similar to that used in BC salmon farms; Nordrum et al. 1997. P_F reflects both fecal and metabolic losses of ingested phosphorus.

Interpretation

Recent advances in feed and feeding practices in the finfish aquaculture industry have decreased the nutrient load per tonne of fish produced (Hardy and Gatlin 2002). However, total nutrient loads from marine finfish sites have increased because of expansion in the number, size, and production levels of sites. Only two more sites (a 2.1% increase) were feeding fish in 2004 than in 2003, but nutrient loads increased 12.2%, as shown by the increased amount of feed used by the industry (Table 13).

Feed usage data submitted before 2003 are not as complete as later data; however, total feed use for the finfish aquaculture industry in 2000 was estimated at 55,533 tonnes. That means that nutrient loads in 2004 may be approximately 80% higher than nutrient loads from finfish aquaculture in 2000.

The most noticeable impacts of nutrients in fish farm wastes are associated with organic carbon (from both feces and waste feed) deposited on bottom sediments. The biological breakdown of excess organic matter in bottom sediments can eliminate oxygen and produce toxic substances, eliminating all organisms except certain anaerobic bacteria. These impacts do not occur at all sites, and when they occur are generally limited to the area immediately around the net pen sites. These changes last from several months to several years once the site ceases operation (Brooks and Mahnken 2003); in some cases, effects have been shown to last for 4 to 7 years (Brooks et al. 2004).

Nitrogen and phosphorus loads have less noticeable impacts because they are essential nutrients and are rapidly used by marine macroalgae and phytoplankton. Exceptionally high levels of these nutrients can lead to eutrophication. In severe cases, eutrophication decreases oxygen levels in the sediment or water column, with corresponding impacts on species assemblages of marine organisms.

Increased nitrogen and phosphorus loads can also alter existing nutrient ratios, which can alter the species makeup of the phytoplankton community. High nitrogen and phosphorus loads relative to silica can produce blooms of toxic dinoflagellates (Holby and Hall 1994). Fish farms in relatively enclosed, low-flow areas have been associated with measurable increases in nutrients and associated eutrophication (Persson 1991; Gowen and Ezzi 1992), whereas other studies have not found such impacts (c.f., reviewed in Brooks and Mahnken 2003; EAO 1997).

Detecting broad impacts associated with nutrient loading from finfish aquaculture is difficult because increased nutrient loads from expanding production do not necessarily produce a corresponding increase in impacts to the environment. Impacts associated with increased nutrient loads depend on natural factors that can vary widely from site to site (e.g., currents or tides, nutrient uptake or recycling rate, background nutrient concentration, other human sources, type of surrounding habitat, and biotic communities).

It is difficult to compare nutrient loads coming from fish farms with other human and natural sources of nutrients because individual finfish sites are relatively small point sources (as opposed to sewage outfalls) and are located where there is little additional loading from human sources and where there is relatively little information on natural loadings. Compared to such sources as the Fraser River, which contributes an estimated 171,000 tonnes of particulate organic carbon per year (Johannessen et al. 2003), the annual loads from BC finfish farms are small. Increased nutrient loads from finfish farms in areas that are already experiencing large nutrient loads from natural and human sources (e.g., Georgia Basin) may have little additional cumulative effect. In contrast, however, increased nutrient loads from finfish farms in more remote areas that are subject to less natural loading may have greater and more discernible effects.

Supplementary Information: Impact of Waste from Finfish Net Pens on Soft Sediment Ecosystems

A recent BC Ministry of Environment (MOE) pilot study investigated the possibility of using changes in benthic community structure as an indicator of impact of waste from salmon net pens. Finfish aquaculture pens in BC are located over a wide range of habitat and biotic community types, but monitoring data have been collected only for sites with soft sediment bottoms, where remote sampling of the unconsolidated sediments was possible.

The study examined MOE monitoring data as well as data collected by various organizations on reference conditions in coastal waters. These data were tested for correlations with benthic community structure and sediment chemistry. It was found that the proportion of non-mobile (sedentariate) marine polychaetes in samples could be used as a simple biotic indicator of gross changes in the balance of major taxonomic groups outside of reference conditions. Polychaetes are marine worms with paired, flattened, bristle-tipped organs of locomotion. They are a dominant, highly diversified group of organisms found on the sea floor, with hundreds of species present in natural marine environments. Polychaetes are used as indicator organisms in environmental monitoring, particularly in situations of organic enrichment of sediments.

A set of criteria was developed to categorize sediment monitoring samples according to the levels of "faunal stress." Faunal stress was deemed to occur when the number and abundance of faunal species fell below the normal variance for benthic communities, based on the reference (control) sites. Ecosystem conditions were classified into four groups by the abundance of organisms, number of species, and type of sedentariate polychaetes present: 1. extremely stressed; 2. recovering fauna; 3. moderately stressed; 4. not impoverished (i.e., not different from reference or control conditions).

The 2000–2003 monitoring data were assessed in light of these four condition categories. Samples in the extremely stressed category ranged from 0 to 38%, depending on the year. Most of the extremely stressed samples occurred at 0 to 30 m from the edges of the finfish net pens, although some were as far as 150 m from the edge (2000 data only). Some level of stress (categories 1, 2, and 3) was noted in about 12% of all samples.

Preliminary results showed that benthic impacts appear to be localized around the fish farm site. This is consistent with research showing that benthic impacts tend to occur within several hundred metres of net pens (Gown and Ezzi 1991; Brooks and Mahnken 2003). Organically enriched sediments are typically processed by bacterial and invertebrate activity fairly rapidly, as long as oxygen is available to penetrate the sediment. Once the fish net pens have been removed from the site, it appears that sediment geochemistry recovers over time, allowing benthic fauna to recolonize the area.

8. Key Indicator: Land cover status of BC's coastal forests

This is a status or impact indicator. It addresses the question: How much have BC's coastal forests been altered by human activities?

The temperate coastal forests of North America, stretching from Alaska to northern California, represent about half of the earth's temperate coastal rainforest ecosystems (Ecotrust 1995). This is the largest contiguous example of such ecosystems, even though large areas have been harvested or cleared in southern BC, Washington, Oregon, and California.

BC's coastal rainforests contain mainly coniferous trees. Conifers are well suited to mild wet winters because they grow year round. Under these conditions, organic matter and soils accumulate quickly, making BC's rainforests one of earth's most productive ecosystems. Moist conditions on the coast reduce the chances of fire, so trees can live for centuries—some coastal Douglas-fir trees are 1000 years old and a few yellow-cedar trees may be more than 2000 years old (Norse 1990). However, natural disturbances such as wildfires, insect outbreaks, and blow-down of forests during strong windstorms have, at times, had considerable effects on the older forests of the BC coast (Lertzman et al. 1996; Brown and Hebda 1998).

First Nations people living on the coast before Europeans arrived cut trees and cleared small areas of land. They set fires to enhance the growth of food plants, hunt game, and protect their settlements from wildfires (Johnson 1999; Turner 1999). Although natural and human-caused disturbances have always been part of the forest ecosystem, the scale and rate of forest disturbance increased after European settlement in the mid-1800s (MacKinnon and Trofymow 1998).

Older Coastal Forests

When discussing the coastal forest, it is important to distinguish between the terms "old growth" and "older forest." An old growth forest is defined by its age and structure.

The most important attributes of old growth forest relevant for biodiversity are the large, old trees, as well as standing dead trees, fallen dead or decaying trees, and a multi-layered canopy with openings that allow light to reach the forest floor (BCMSRM 2003b).

Such attributes were not measured in past forest inventories, so it is not possible to identify the amount and location of true old growth forest. Therefore, the term "older forest"—defined as forest more than 140 years old—is used in this analysis. Because coastal forests were relatively undisturbed until the beginning of European settlement about 140 to 150 years ago, forests categorized as "older forest" are considered to be undisturbed by logging. Most coastal forests older than 140 years have at least some characteristics of "old growth" forests. It is estimated that about three-quarters of older coastal forests (as classified by the BTM) are more than 250 years old and may be considered true old growth forests (T. Niemann, Ministry of Forests and Range, pers. comm., 2005).

Trees in the older forest category range from the towering trees typical of old-growth rainforest to the old but stunted trees of the high-elevation krummholz forests near the treeline. High-elevation forests have little economic value for forestry, but have important ecological and wildlife values. For example, 164 wildlife species live here, either year round or for part of the year (Stevens 1995). Some of these species, such as tailed frogs, spotted owls, ermine, and wolverines, are at risk (CDC 2005).

Forests in Three Coastal Biogeoclimatic Zones

According to the Biogeoclimatic Ecosystem Classification (BEC) system of classifying BC ecosystems, three biogeoclimatic zones are found only on the BC coast (Meidinger and Pojar 1991).

Coastal Western Hemlock zone: This is by far the most extensive zone, accounting for 84% of the forested area of the coast (Malcolm Gray, Business Solutions Branch MSRM, pers. comm., 2004). It occurs at middle to lower elevations. Most of the coastal forest industry's operations take place in this zone because it is more easily accessible and the trees grow bigger. About 35% of the area is young or recently disturbed forest as a result of logging, natural fires, blowdown, and disease; 65% of the area is older forest.

Mountain Hemlock zone: This is the second largest forest ecosystem, covering 15% of the forested area of the coast (M. Gray, pers. comm., 2004). It includes high-elevation and subalpine forests. The forests of this zone are slower growing and occur on steeper terrain than the Coastal Western Hemlock zone, and are thus less accessible or desirable for harvesting. Lower harvest levels combined with a lower frequency of forest fires due to the colder, wetter climate results in a much lower proportion of young and recently disturbed forest (9%) and a higher proportion of older forests (92%).

Coastal Douglas Fir zone: This is the smallest zone; the original extent covered only 1% of the forested area of the coast (M. Gray, pers. comm., 2004). It is under the most intensive pressure from human activities because it occurs entirely on eastern Vancouver Island and the Gulf Islands with a few patches on the Lower Mainland. About half (46%)

of this zone has been converted to human uses, 4% is recently disturbed, 37% is young forest, and only 7% is older forest.

Methodology and Data

Analysis of the Current Status of Forests

The data for this indicator came from provincial Baseline Thematic Mapping (BTM). BTM incorporates data from satellite images with some additional information from 1:20,000 forest inventory maps (where that inventory is available) to aid in distinguishing between old and young forest. The BTM data (scale 1:100,000) represent land types as of approximately the mid-1990s (1992–1999), depending on when the satellite images were acquired. The coastal area analyzed for this indicator covered the Coast and Mountains and Georgia Depression ecoprovinces.

To calculate the area of coastal land covers and land uses (Table 14, Figure 16), the 19 land types designated in BTM were grouped into five categories:

1. Standing forest: all categories of forests more than 20 years old.

2. Recently disturbed forest: forests that have been selectively logged, clear-cut, or burned in the last 20 years.

3. Natural non-forest: alpine areas, avalanche chutes, barren surfaces, ice, shrub, wetlands such as bogs and fens, and rangeland (natural grasslands, some of which may be used for grazing).

4. Water: lakes, rivers, and the intertidal portion of estuaries.

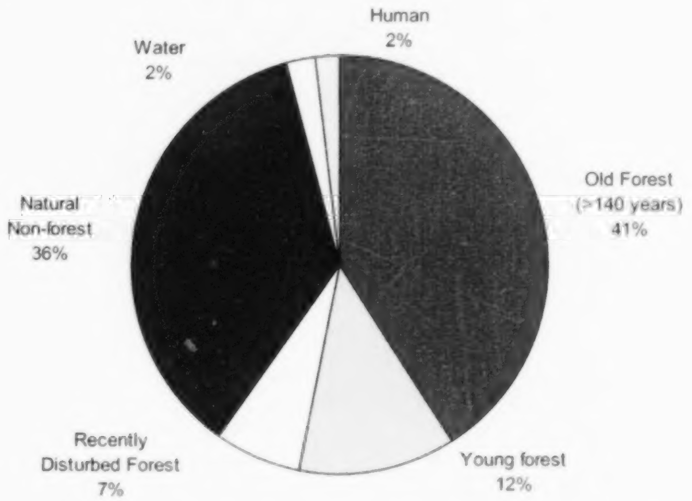
5. Human uses: urban areas, agricultural and mixed agricultural-urban areas, mines, and recreation sites (primarily rural golf courses and ski hills).

Table 14. Extent of land cover and land use categories in coastal BC in the mid-1990s.

Land cover or land use	Area (ha)	% of total
1. Standing forest		
Older forest (≥140 yrs)	8,302,958	40.9
Younger forest (20-140 yrs)	2,478,587	12.2
Total	10,781,545	53.1
2. Recently disturbed forest		
Recently logged	1,310,502	
Selectively logged	14,817	
Burned	18,761	
Total	1,344,080	6.6
3. Natural non-forest		
Alpine	3,318,308	
Avalanche chutes	1,466,969	
Barren surfaces	237,713	
Rangeland	5,904	
Shrub	32,625	
Wetland	262,463	
Ice	1,978,346	
Total	7,302,328	36.0
4. Water		
Estuary	28,868	
Fresh water (lakes, rivers)	428,030	
Total	456,898	2.3
5. Human uses		
Urban	224,734	
Agriculture	119,065	
Mixed agriculture-urban	36,553	
Mine	7,059	
Recreation	5,896	
Total	393,307	1.9
Grand total area	20,278,158	

Source: Malcolm Gray, Business Solutions Branch MSRM, pers. comm., 2004.

Figure 16: Proportion of land cover and land use on the BC coast in the mid-1990s.



Source: Malcolm Gray, Business Solutions Branch MSRM, pers. comm., 2004.

This indicator shows that in the mid-1990s, about 40% of the total area of the coast was still in older growth trees (over 140 years old). About 53% of the land area of coastal BC was currently forested with trees at least 20 years old (Figure 16), and 7% was recently disturbed forest (logged within the last 20 years). Considerably more logging had taken place in the Coastal Western Hemlock zone (about 35% of this zone is younger than 140 years old) than in the Mountain Hemlock zone, of which only about 9% was younger than 140 years old.

Thirty-six percent of the coastal area was naturally non-forested (alpine, ice, barren, shrub, grasslands, and wetlands) and 2% of the coastal area was freshwater (lakes, river and estuaries) (for a total of 38% of land area of coast). Only 2% of the total land area (including naturally non-forested land) of the coast had been entirely converted to human uses (principally through urbanization and agriculture).

Analysis of the Status of Coastal Forests Two Centuries Ago

An estimate of the extent of coastal forests was also made based on the data in Table 14 (Malcolm Gray, Business Solutions Branch MSRM, pers. comm., 2004). It included the area in the categories for recently disturbed forest, young forest, and human use (land converted for human uses) using the following assumptions:

- All areas converted to human uses were forest. In reality, some lands converted for human use may have been wetlands, grasslands, or other ecosystems, rather than forests.

- There were no natural or human-caused disturbances to the forests before Europeans arrived and therefore all forests were older. In reality, human disturbance in coastal forests has occurred for thousands of years, but the extent is not known.

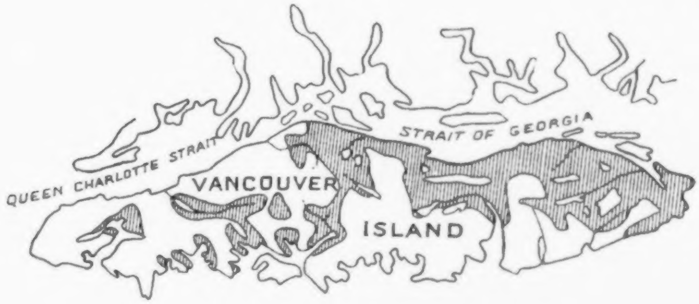
Based on these assumptions, an estimated maximum of 12.5 million hectares, or 62% of the total BC coastal area may have been older forest before European settlement. This means about 3% of the original coastal forest has been permanently converted to human uses (mainly in the Coastal Douglas-fir zone of the lower Fraser Valley and eastern Vancouver Island where most of the province's population lives).

Interpretation

Overall, it appears that about 20% of the land area on the BC coast has experienced some kind of disturbance since the early 1800s. This disturbance includes logging, land conversion, other human activities, and natural disturbance. The estimate of 62% for the original extent of older forests, based on the assumptions described, means that about two-thirds of the coastal older forests was still undisturbed in the mid-1990s when the BTM data were collected.

It is difficult to confidently estimate the proportions of young and older forest that existed in pre-settlement times because coastal wildfires occur on an episodic rather than regular cycle (Agee 1993). Wildfire episodes are known to have burned about 800,000 ha, primarily on southeastern Vancouver Island, in the mid-1600s (Schmidt 1957) (see Figure 17). On northern Vancouver Island, individual wildfires of 30,000 ha or more have been documented dating to the mid-1500s, and a blowdown of a similar size occurred in 1906 (John Parminter, Ministry of Forests and Range, pers. comm., 2005).

Figure 17: Approximate area of forest burned on Vancouver Island during the mid-1600s.



Source: Schmidt 1957.

9. Secondary Indicator: Trends in three land-use measures in 55 watersheds of the Campbell River Forest District

This is a pressure indicator. It addresses the question: What is the impact of human activities on coastal forest ecosystems?

Land use measures provide information on the extent to which watersheds are affected by human activities and provide a new way to monitor watersheds and ecosystem sustainability. This indicator examined three land use measures in 55 watersheds of the Ministry of Forests and Range's Campbell River Forest District. The measures examined were road density, riparian disturbance, and forest disturbance.

The density of roads in an area shows the impact of human activities.

Roads:

- are often built in valley bottoms where riparian areas are located;
- fragment and degrade habitat; roads alter water flow patterns over the land and increase the amount of sediment that enters streams. For example, in a forested part of Montana, road densities higher than 100 m/km^2 decreased the number of bull trout spawning sites (Baxter et al. 1999).
- increase animal mortality through roadkill and create barriers to amphibian migration;
- increase habitat and wildlife disturbance (facilitating access by hunters, hikers, etc.);
- reduce populations of some native species while increasing the number of non-native species that can access the area (Demarchi et al. 1990).

Riparian areas border streams, lakes, and wetlands. Nearly 60% of BC's species at risk depend on riparian habitat at some time in their life cycle (Stevens et al. 1995).

Disturbances in riparian areas affect ecosystems because riparian areas:

- function as floodplains and as important wildlife corridors through the forest (Alaback and Pojar 1997);
- have vegetation that stabilizes streambank or shoreline, shades adjacent water, contributes nutrients and food to the aquatic ecosystem from fallen leaves and insects, and provides both aquatic and terrestrial habitat.

Forest disturbance, such as harvesting and clearing, affects both terrestrial and aquatic ecosystems because:

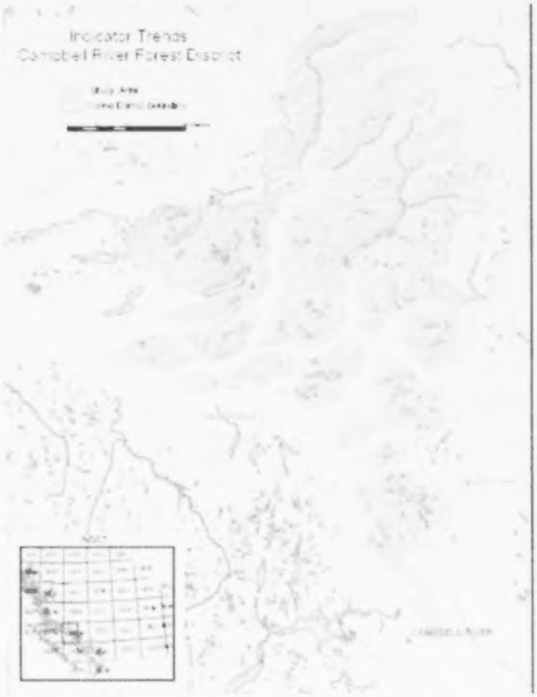
- important habitat structure provided by large, older trees is lost;
- tree stand removal causes habitat fragmentation and reduces forest interior habitats that some species require;
- changes in forest density and age structure alter transpiration and evaporation rates;

- the rate at which snow melts and the volume and rate of surface runoff is altered.

This indicator was first developed as a pilot project for four watersheds near Fort St. James. For this paper, the study area was within the Campbell River Forest District and included an area on the mainland and coastal islands from Quadra Island to Hardwicke Island (Figure 18). The Vancouver Island portion of the Campbell River Forest District was not included. The study area covers 272,000 ha, consisting of 55 watersheds ranging in size from 50 to 30,000 ha. This area of the coast has a small population, urban development occupies less that 1% of the area (mostly on Quadra Island), and it has no identifiable burned forest area.

Although this indicator reports on a relatively small area of the coast, it is expected that these three land use measures will be applied to a larger area of the coast (as well as the interior of the province) in future.

Figure 18: Location of the 55 watersheds in part of the Campbell River Forest District where road density, riparian disturbance, and forest disturbance were measured.



Methodology and Data

The three land use measures chosen for analysis were measurable from existing data and are known to affect forest ecosystems.

Road density: Reported as kilometres of roads per square kilometre of forest land.

Riparian disturbance: The length of riparian habitat that has been harvested, cleared, or burned within 30 m of a lake, stream, or wetland. It is reported as a proportion of total riparian area of forested land in the watershed. Note, however, that the scale of this analysis does not include the many small streams less than 1.5 m wide. This analysis did not discriminate between fish-bearing and non-fish-bearing streams.

Forest disturbance: The area of forest land that has been harvested or cleared in the past 20 years, including regeneration. It is measured in hectares and expressed as a proportion of total forested land in the watershed.

A Geographic Information System (GIS) was used to compile data from a variety of sources:

- the Watershed Statistics database provided data on watershed boundaries.
- Baseline Thematic Mapping (BTM) provided data on forested land and forest disturbance.
- 1:20,000 base mapping (TRIM) contained information on road location and length, and stream location, length, and elevation.
- the Forest Inventory database provided data on forest disturbance history and forest stand characteristics.

Data were obtained from the Ministry of Sustainable Resource Management, Victoria, for a 17-year period from 1987 to 2004. Data were available for 1987, 1993, 1998, and 2004. This analysis includes both productive and unproductive forest (e.g., krummholz).

GIS coverage layers were developed for each land use measure (road density, riparian disturbance, and forest disturbance) for four years: 1987, 1993, 1998, and 2004. Once land use, base mapping, and forest inventory data had been merged into a single coverage, the coverages were verified using satellite images and air photos from each time point. Statistics were then derived for the number of watersheds and the proportion of total watershed area for each land-use measure.

For each land use measure, the 55 watersheds were categorized into four levels of disturbance: high, moderate, low, and no disturbance. Each measure was then analyzed separately.

The following steps were used to determine the number of watersheds within each disturbance level:

1. 1987 was used as the baseline against which change in subsequent years was measured.

2. Watersheds without disturbance in 1987 were removed from the dataset and counted as No Disturbance.

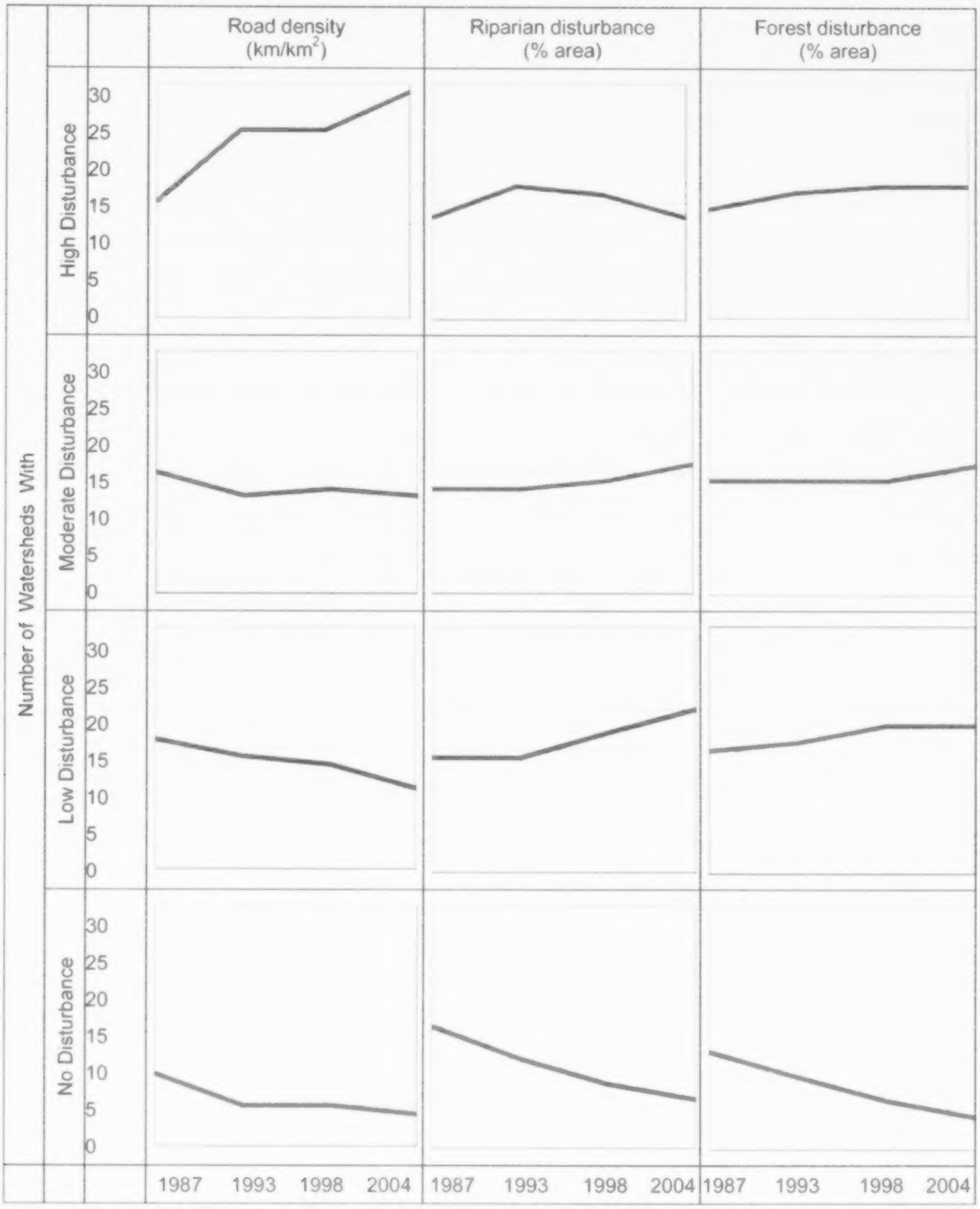
3. Watersheds registering disturbance in 1987 were sorted from least to most disturbed.

4. The list of sorted watersheds was divided into thirds. The third of watersheds with least disturbance were classified as having "low" disturbance. The third of watersheds with the most disturbance were classified as "high." The remaining watersheds, between low and high, were classed as "moderate."

5. The maximum disturbance value within each class was used as the threshold between low, moderate, and high. These thresholds provided the basis for classifying watershed data from 1993, 1998, and 2004, essentially measuring change against the 1987 baseline.

Figure 19 shows the number of watersheds with high, moderate, low, and no disturbance levels in each of the three measures. Forty-eight watersheds showed disturbance in all three land use measures. The number of watersheds with no disturbance from any of the three land use measures was five in 1987 and 1993, four in 1998, and three in 2003.

Figure 19: Number of watersheds with high, moderate, low, and no disturbance, for three land-use measures: road density (km of road/km^2), riparian disturbance (% riparian area), and forest disturbance (% forest area), over time, in the study of 55 watersheds in the Campbell River Forest District.



Source: Malcolm Gray, Business Solutions Branch, BCMSRM, pers. comm., 2005.

Interpretation

During the pilot project in the Fort St. James Forest District, the reliability and accuracy of this method of data integration were assessed (BCMSRM 2004b). The results were found to be reliable when the objective is to understand the general health of watersheds relative to each other.

These measures reflect the total amount of disturbance of the forest for three points in time. The change in disturbance between two points in time is the sum of new disturbance minus the amount of recovery of previously disturbed area. These measures do not show the rate of change over time.

In the Campbell River study area, between 1987 and 2004, the number of undisturbed watersheds decreased. Although the three land use measures are not independent of one another (for example, forest harvesting is generally preceded by road building), it shows that the level of disturbance became more pervasive over time. In 2004, forestry activities had moved into two of the five watersheds that were without industrial development in 1987. An increase of three new watersheds every 17 years is not a high rate, but within a landscape context where 52 of 55 watersheds currently show some disturbance, there may be more cause for concern.

In addition to a decrease in the number of undisturbed watersheds, disturbance of all types has increased within the area of analysis between 1987 and 2004 (Figure 19). The decline in number of watersheds with high riparian disturbance suggests that the disturbed riparian areas are recovering, that is, the older logged areas are growing beyond the "disturbance in the last 20 years" category that defines disturbance in this study.

These measures provide some perspective on the impact of forestry in a coastal landscape where other forms of human disturbance are negligible. Within the Campbell River Forest District, disturbance from forestry and roads has spread into some of the few remaining undeveloped watersheds within the District. Although the data are limited to 55 watersheds, given the continuing demands of our growing human population, similar trends are likely happening in other coastal forests.

WHAT IS HAPPENING IN THE ENVIRONMENT?

Over the next 20 years, the coastal population of BC is projected to increase by a million people to more than 4 million residents. It is inevitable that pressure from this growing population and from economic activities along the whole coast will increase. In addition to loss of natural habitat to industrial, residential, and shoreline development, there will be increasing pressure from vehicle and vessel traffic, water demand, sewage discharge, urban runoff, solid waste disposal, releases of greenhouse gases, excess nutrients, and air and water pollutants. The areas with the greatest local impacts will continue to be the metropolitan areas of Vancouver and Victoria and the east coast of Vancouver Island, where population growth rates are expected to remain above most other regions of the province. One symptom of the increasing pressure is that closures of shellfish harvesting areas have increased steadily since the 1970s, primarily as a result of increasing population and associated sewage discharges.

The indicators reported in this paper show a mixture of environmental pressures and impacts and responses to those pressures. They also expose large differences in the type and scale of pressures and impacts between the less populated central and northern areas of the coast and the densely populated areas of the south coast.

In BC as a whole, only 2% of the land area has been converted to human uses such as urban development, agriculture, mining, and recreation. In contrast, in the Greater Vancouver Regional District (GVRD), half of the land area is occupied by such uses. In areas with the province's highest population density, high marine traffic volumes—with attendant emissions of air and water pollutants—are among many other stresses on marine ecosystems. Currently Victoria, Vancouver, and Juan de Fuca Strait Vessel Traffic Service zones have the highest traffic volumes. At present, the marine traffic densities along the north coast of BC are relatively low compared to the south coast, but with the planned expansion of the port at Prince Rupert, traffic along the north coast is expected to increase.

The indicators also show how much of the coastal region outside of the most populated area remains relatively undisturbed. For example, before the beginning of European settlement, an estimated 62% of the total BC coastal area was older forests (more than 140 years old). Of the land that was naturally forested, 3% of the original coastal forest has been permanently converted to human uses such as urban development and agriculture, mainly in the lower Fraser Valley and eastern Vancouver Island where population density is highest. However, it is estimated that two-thirds of the total area of the coast that was forested before the beginning of European settlement was still forested with trees more than 140 years old as of the mid-1990s (about 40% of the area of coastal BC). Opportunities still exist to protect important environmental values as part of estuary conservation planning. The tenure status of the larger estuaries reported on in this paper showed that more than half of the total estuary intertidal area had neither a conservation nor an economic interest tenure.

Although further economic development and population growth along the coast will continue, there are choices in how much, how soon, and in what way this growth should occur. A healthy, functioning ecosystem supports recreational and cultural values that are beyond measure, yet the health of the coastal economy also depends on a sustainable resource base. BC coastal communities have been making difficult choices between economic and environmental values for decades. The decisions will not get easier in the future as the province grapples with issues such as offshore oil and gas exploration.

WHAT IS BEING DONE ABOUT IT?

The negative impacts of population growth can be mitigated by strong growth-management policies and strategies, as well as by adoption of technology and participation in initiatives that reduce consumption or emissions to the environment.

Examples of policies that lessen the impact of urban growth on the natural environment include limiting growth outside of urban core areas, increasing densification of these core areas, providing mass transit, supplying incentives for using environmentally sound technology, and encouraging low impact development infrastructure and green building strategies. Indicators in this paper showed the impact of such efforts. For example "smart growth" strategies appear to be slowing the rate that land is converted to urban uses in the GVRD. Between 1986 and 2001, the urban use area increased by about 2% and areas of mixed agriculture and urban use expanded by about 5%. Given that the GVRD population increased by 25% within that period (1991–2001), it appears that efforts to contain urban sprawl and "smart growth" planning approaches within the GVRD have had a positive influence. From 1998 to 2002, the rate of conversion to urban use and of deforestation had fallen to one-tenth the rate of the previous five years, a further indication that planning efforts are slowing the rate of sprawl.

Another indication of effort to reduce human impacts is that the proportion of the population served by secondary sewage treatment facilities increased substantially since 1983, showing that there has been a significant investment in environmental infrastructure. Virtually all of the population on sewers in the Georgia Basin had some form of treatment and three-quarters of the population outside of the Georgia Basin also had secondary treatment of the discharged sewage.

Some important initiatives and programs are aimed at protecting the coastal environment and managing the impacts of human population and economic activities:

Regulatory Initiatives

- Canada Shipping Act: After the Exxon Valdez spill, the international community developed the International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC'90) to enable countries to be better prepared for spills. Canada ratified this agreement and modified the Canada Shipping Act in 1995 to include restrictions on tankers, barges, and oil-handling facilities. Companies in BC shipping oil are now required by the Canada Shipping Act to retain a certified response organization to respond to a major oil spill. In most areas, this also includes a Shipboard Oil Pollution Emergency Plan as part of an oil-spill contingency plan. Fees are collected from shipping companies to support oil-spill response preparedness.
- The Forest and Range Practices Act, 2004. The forest industry is guided by this act, which replaces the Forest Practices Code introduced in 1995. Operators are accountable for results and strategies in their forest stewardship plan, to ensure the conservation of a wide range of values including soils, timber, wildlife, water, fish, biodiversity, cultural heritage resources, forage, and plant communities.

Land-Use Planning

Integrated land-use planning on Crown lands is the responsibility of the Integrated Land Management Agency of the Ministry of Agriculture and Lands. This agency ensures that resource management represents a balance of community, economic, and environmental needs and provides a process for agencies, stakeholders, advocacy groups, communities, and individuals to engage in collaborative decision-making about land use and resource management.

Although local plans cover smaller areas, strategic planning enables land use decisions to be made over large regions or sub-regions of the province. Strategic land-use plans help ensure that resource management decisions take into account the needs of communities, the economy, and the environment. The land-use planning process identifies needs, defines land-use zones, sets objectives, and develops strategies for managing resources in those zones. Each land-use plan is tailored to the needs of the local community. The planning process involves significant public and stakeholder participation. Some significant plans in coastal BC include the following:

- The Central Coast Land and Resource Management Plan (LRMP): The plan, which is currently under way, encompasses a large region of the BC coast of about 4.8 million hectares. This is an area half again as large as Vancouver Island; it includes portions of the Kitimat-Stikine, Central Coast, Cariboo, and mainland portions of the Mount Waddington and Comox-Strathcona regional districts. First Nations account for more than half of the population in the plan area, and many are actively participating in the planning process.
- North Coast Land and Resource Management Plan: The public planning table of the North Coast LRMP began meeting in February 2002. The final recommendations were submitted to government-to-government negotiations between the provincial government and First Nations in the area. The approved plan will provide a comprehensive strategic direction to guide the management of Crown land and resources. The North Coast LRMP planning boundaries encompass approximately 1.8 million hectares. The population of the plan area is approximately 17,000; most of the inhabitants live in Prince Rupert. Other communities include Gitxaala, Hartley Bay, Lax Kw'alaams, Metlakatla, Oona River, and Port Edward.
- The Haida Gwaii/Queen Charlotte Islands Land Use Plan: Beginning with a community planning forum in September 2003, the goal has been to develop recommendations on a land-use plan that is ecosystem-based, maintains spiritual and cultural values, and fosters community well-being, while opening up economic opportunities to all people of Haida Gwaii/Queen Charlotte Islands. The final Land Use Plan Recommendations report was delivered in January 2006.

For more information on coastal land planning, including Clayoquot Sound regional plans, the Sea-to-Sky Land and Resource Management Plan, and the Vancouver Island Land Use Plan (completed in 2000), see *ilmbwww.gov.bc.ca/ilmb/lup/lrmp/index.htm*

Local governments have responsibility for managing land use on private land. Many are applying smart growth principles to their development regulatory tools that include regional growth strategies, official community plans, zoning bylaws, and development of standards and guidelines. Communities like Maple Ridge and Squamish are pilot communities that are trying to apply comprehensive smart growth principles.

Empowered by provincial legislation, numerous local governments are implementing regional growth strategies on the coast:

- Greater Vancouver Regional District
- Capital Regional District
- Regional District of Nanaimo
- Fraser Valley Regional District
- Squamish Regional District (a strategy to manage rapid urban growth from Squamish to Pemberton is under development).

Canada's National Programme of Action (NPA)

The NPA for the Protection of the Marine Environment from Land-Based Activities was developed as a full partnership between federal, provincial, and territorial governments, in consultation with Aboriginal peoples, stakeholders (environmental groups, industry, academia, and the private sector) and other interested Canadians. The NPA focuses on Canada's efforts to protect the marine environment through improved coordination and harmonization of all levels of government.

The goals of the NPA are to:

- protect human health and the environment,
- reduce degradation of the marine environment,
- remediate damaged areas,
- promote conservation and sustainable use of marine resources, and
- maintain the productive capacity and biodiversity of the marine environment.

For more information and updates, see *www.npa-pan.ca/index_e.htm.*

Industry Initiatives

Corporations and businesses are responding to the growing concern for environmental responsibility expressed by consumers and the public, as well as the growing recognition that sustainable environmental practices are good for business. Among many initiatives are the following:

- Canadian Business for Social Responsibility (CBSR) was founded in 1995 as a non-profit, national organization of Canadian companies, small and large, that have committed to operate in a socially, environmentally, and financially responsible manner. The organization provides networking, advisory services, training programs, access to research and reports, contacts, and planning documents for businesses of all sizes. See: *www.cbsr.bc.ca/default.htm.*

Small and medium-sized businesses can seek guidance from programs designed to help reduce the environmental impact of their operations.

- GVRD Smart Steps encourages businesses to cultivate the concept of eco-efficiency to create more goods and services with fewer resources, while creating less waste and pollution. The Smart Steps program focuses on business practices that use energy and materials efficiently and use renewable resources and non-toxic materials. The intent is to improve environmental performance by conserving materials and energy while reducing costs and waste. The program provides industry-specific information, business tools, and case studies on a comprehensive website: *www.gvrd.bc.ca/smartsteps/*.
- The Green Workplace is a service designed to help small to medium sized businesses reduce the environmental impact of their operations. The program is coordinated by the Environmental Youth Alliance (EYA), which hires and trains youth teams to conduct the audits as part of an employment skills program. The program includes confidential audits of business operations and assistance to find information on cost-saving solutions, contacts, and service providers. For more, see *www.eya.ca/gwp/*.

Product Certification

Certification of products provides an incentive to industries to operate sustainably by developing standards and monitoring programs that can be used by consumers who want to support environmentally responsible industries. Examples include:

- **Forestry certification:** Beginning in the 1990s, third-party certification programs to identify and label forest products that originate in sustainably managed forests have been expanding. Programs exist at the national and international levels and have spread globally. For Canadian forests, at least four voluntary programs certify forests according to a set of environmental and social standards. Producers and manufacturers along the supply chain also can be certified to ensure that the final product bearing the logo originated from a certified forest. Programs include:
  - The Forest Stewardship Council is an international system covering forest management practices and the tracking and labelling of certified products and paper products with recycled content.
  - The Sustainable Forestry Initiative® Program is a sustainable forest management standard that targets large industrial operations in Canada and the United States.
  - The Canadian Standards Association sets national standards for sustainable forest management and the tracking and labelling of certified material. It covers operations in Canada.
  - The Program for the Endorsement of Forest Certification Schemes is a global umbrella organization for mutual recognition of national products that meet international forest certification standards.

  More about forestry certification and the details of each certification system can be found at: *www.metafore.org/index*.

- **The Marine Stewardship Council** is an international organization that has developed a wild fisheries certification standard consistent with the FAO guidelines for ecolabelling of fisheries. The Council operates an accreditation program for independent bodies that do the assessments. Fisheries whose practices meet this standard earn the right to display the MSC logo on their products. The BC Salmon Marketing Council, acting for both harvesters and processors of wild salmon, initiated the MSC certification process in September 2001. An evaluation team has been established in consultation with stakeholders, and performance indicators and scoring guidelines were published in June 2003.

Stewardship Partnership Initiatives

- **Stewardship Canada** is a partnership of federal, provincial, and environmental agencies that co-sponsor a website portal and, among other projects, have produced a set of practical guides on stewardship of different types of environments. They have produced the *Coastal Shore Stewardship: A Guide for Planners, Builders and Developers,* in response to the growing commercial and industrial development along shorelines. The guide provides information about shore zone habitats, outlines best management practices, and illustrates how coastal developments can be undertaken without destroying fragile coastal processes. It is available at: *dev.stewardshipcanada.ca/sc_bc/stew_series/NSCbc_stewseries.asp.*
- The **Pacific Estuary Conservation Program** (PECP) is a group of government agencies and non-government organizations working together to conserve waterfowl and shorebird habitat in estuaries throughout BC. PECP began in 1987 and has acquired nearly 2000 ha of shoreline and intertidal habitats. PECP has also played a role in designating for conservation more than 56,000 ha of wildlife habitat in estuaries and intertidal areas (NRTEE 2004).
- **Labour Environmental Alliance Society** (LEAS) includes members representing a wide variety of BC industry, trade unions, and environmental groups committed to developing strategies for workers and communities working toward more environmentally sustainable activities. The LEAS "WoodnotWaste" program encourages marketplace competition for logs salvaged from the Fraser Estuary. In partnership with beachcombers, LEAS helped form the Western Log Sort and Salvage Co-op. *www.leas.ca/pdf/WoodNotWaste.pdf.*

Managing the Impacts of Tourism

The long-term sustainability of the BC tourism industry depends on the beauty and quality of the natural environment. Realizing this, some tourism business operators have made large investments in developing environmentally sensitive tourism operations. After consultation with the industry, the Tourism Industry Association of Canada (2005) released the Code of Ethics and Guidelines for Sustainable Tourism. It emphasizes the importance of protecting, enhancing, and restoring natural resources and minimizing the negative impacts of tourism. The BC Wilderness Tourism Association (2002) has also produced a code of conduct that includes training staff in the appropriate standards, educating the recreational public, and maintaining good community relations.

Guidelines for operating around whales have been developed in collaboration with the Veins of Life Marine Mammal Program (Veins of Life 2005), Fisheries and Oceans Canada, National Marine Fisheries Service, and Whale Watch Operators Association Northwest. They ask that boaters slow down when approaching whales and never go closer than 100 m; also boaters should keep clear of the whales' path, approach and depart whales from the side, move parallel to the direction of the whales, and limit viewing time to less than 30 minutes. These guidelines not only apply to whale watching operators but also to recreational boaters, who may not be aware of how they may be disturbing the whales or that approaching whales too closely is against the law under the Fisheries Act (DFO 2005).

- Detailed "Be Whale Wise" guidelines are available at: *salishsea.ca/m3/assets/guidelines10-3.pdf* or from The Veins of Life Watershed Society, Victoria, BC.
- The Whale Watch Operators Association Northwest has developed more stringent Best Management Practice Guidelines, which are available at: *www.nwwhalewatchers.org/guidelines.html* or from Whale Watch Operators Association Northwest, P O Box 2404, Friday Harbor, WA, 98250.

Many environmental impacts of recreational boating can be minimized by preventing spills during refuelling, by using environmentally friendly cleaning solutions, and by improving how boaters clean bilge and hulls, maintain engines, and dispose of garbage. For advice:

- The Guide to Green Boating *www.georgiastrait.org/greenboating.php* or contact: the Georgia Strait Alliance, #201-195 Commercial St., Nanaimo, BC V9R 5G5. Tel: 250-753-3459, e-mail: gsa@georgiastrait.org.
- "Protecting the Aquatic Environment: A Boater's Guide" (Fisheries and Oceans Canada 1998) *www.p2pays.org/ref/02/01990/english.pdf* or contact Fisheries and Oceans Canada, Pacific Region, Suite 200-401 Burrard Street, Vancouver, BCV6C 3S4; Tel: 604-666-0384.

In recent years, the cruise ship industry has been developing new environmental policies and waste treatment technologies that go beyond international standards (Dobson et al. 2002); it is not known how many ships cruising BC waters meet these more rigorous standards.

WHAT YOU CAN DO

The actions of individuals count, whether it is a positive or negative contribution. For example, more than half of the oil pollution in the world's oceans comes from land-based runoff entering storm drains and streams that empty into the ocean (Smithsonian Institute 1995). Much of this is oil from vehicles that drip oil on road surfaces—the oily road runoff from a city of 5 million people can contribute as much oil to the marine environment as one large tanker spill.

Individuals can reduce their impact on the coastal environment and participate in programs to protect it in many ways:

- Patronize green businesses and buy certified products (such as those listed above).
- Encourage green workplace efforts.
- Get involved in local stewardship projects.

Support "Green" Businesses: Consumer can choose to support businesses that have low-environmental-impact products or services. Look for a certification logo, such as:

- Independent forestry certification programs or the Marine Stewardship Council, both described above.
- The Green Leaf Eco-Rating Program, which is an initiative of the Hotel Association of Canada. It rates hotels based on a comprehensive evaluation of a property's policies and principles around water and energy conservation, waste reduction, and the use of hazardous substances. So far, more than 150 properties have qualified for a Green Leaf rating, and many more have enrolled and await a designation. *www.life.ca/nl/66/ecotravel.html*.

Greening The Workplace: Support and encourage efforts at your workplace toward sustainable business practices:

- Instead of relying on single passenger cars to commute to work, use mass transit, car pools or van pools, bicycles, and other alternatives to relieve traffic pressure on the environment.
- Make an effort to recycle, conserve energy and water, and reduce waste. For example, the Foreign Affairs Canada website (*www.dfait-maeci.gc.ca/sustain/EnvironMan/system/greenop/index-en.asp*) provides tips on "greening" your office, meetings, transportation, purchasing, human resources, and other work-related activities.

Stewardship Participation: Seek out community groups that are concerned with stewardship or sustainability issues and get involved, or help form a group. Stewardship initiatives specifically addressing protection of the marine environment include:

- The Living by Water Project, which began in 1997, promotes the value of maintaining healthy shorelines of both fresh and marine waterbodies. It supports individuals and groups working toward this goal by providing publications, workshops, and programs to make it easier to develop the tools and find the capacity to operate. Their comprehensive reference, "On the Living Edge: Handbook for Waterfront Living" is available at: *www.livingbywater.ca.*

- Keeping Oil Out of Our Harbour program. This is a partnership supported financially by the Greater Victoria Harbour Authority and includes the Georgia Strait Alliance and the Sierra Club of Canada. It is designed to reduce oil and gas pollution from boats pumping bilge water into Victoria Harbour. The program distributes oil absorbent pads to boaters free of charge when they register for moorage at Greater Victoria Harbour Authority docks.
- Green Boating Program: This program from the Georgia Strait Alliance is aimed at the estimated 400,000 recreational sail and power boaters in the province (most are in the Strait of Georgia). The program works with boaters, marina operators, government officials, and others in the region to prevent pollution from bilge pumping, sewage discharge, engine maintenance, haul outs, garbage disposal, and other boating sources. It provides a green boating guide, and links to more information at *www.georgiastrait.org/greenboating.php.*

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Climate Change

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Climate Change

BACKGROUND

The United Nations Intergovernmental Panel on Climate Change (IPCC) and the national science academies of eleven nations, including Canada and United States, have recognized that the Earth's atmosphere is warming and that human activities that release greenhouse gases are an important cause. Warming of the atmosphere affects the temperature of air, land, and water, which in turn affects patterns of precipitation, evaporation, and wind, as well as ocean temperature and currents. This paper presents indicators of climate change for British Columbia, with emphasis on the coastal region.

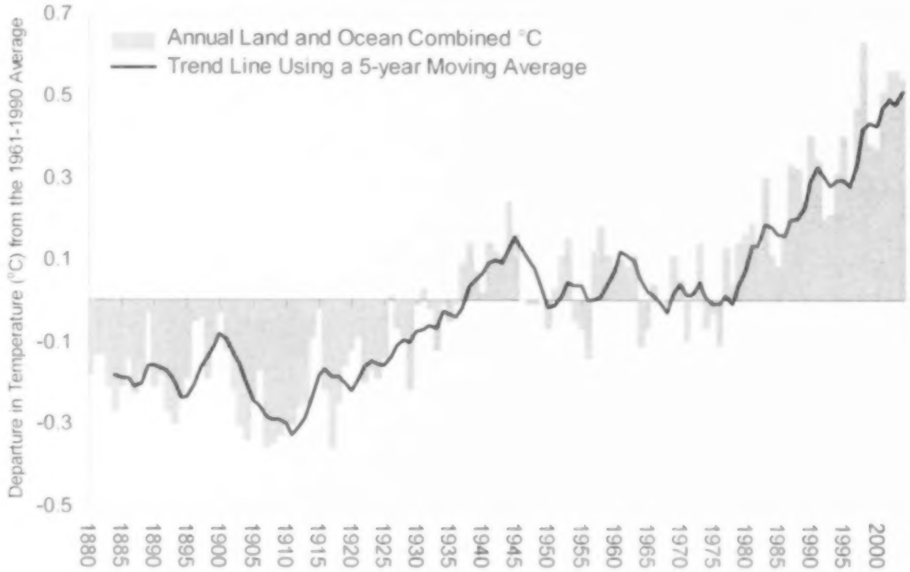
Greenhouse gases are atmospheric gases such as carbon dioxide, methane, and nitrous oxide. They trap solar energy, warming the atmosphere and the surface of the Earth, and play a critical role in maintaining the temperature of the Earth within a range suitable for life. However, as the levels of these gases build up in the atmosphere, they act like the transparent roof of a greenhouse, which allows in sunlight while trapping the heat energy.

GREENHOUSE GASES

Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_20), and other trace compounds. These gases are released into the atmosphere by many naturally occurring processes as well as by human activity such as fossil fuel combustion, deforestation, agriculture, and industrial activity. Human-created greenhouse gases include perfluorocarbons (PFCs), which are a byproduct of aluminum production; sulfurhexafluoride (SF_6), which is used minimally in electrical switches; and hydrofluorocarbons (HFCs), which now replace the ozone-depleting chlorinated fluorocarbons (CFCs) in many applications.

Records show that global temperatures, averaged world-wide over the land and sea, rose 0.6 ± 0.2°C during the 20th century (see Figure 1). The year 1998 was the warmest year since instrument records began in 1861. The next four warmest years have all occurred since 2000. Although natural forces such as solar and volcanic activity may have contributed, the IPCC attributes most of the warming of the last 50 years to human activities that release greenhouse gases into the atmosphere (IPCC 2001b). Long-term records show that CO_2 in the atmosphere has risen from pre-industrial concentrations of about 280 parts per million (ppm) in 1750 to about 375 ppm today. The IPCC concluded that "emissions of CO_2 due to fossil fuel burning are virtually certain to be the dominant influence on the trends in atmospheric CO_2 concentrations during the 21st century" (IPCC 2001b).

Figure 1. Annual global land temperature and ocean temperature (°C), relative to the average temperature for 1961–1990.



Source: National Oceanic and Atmosphere Administration (NOAA)
http://lwf.ncdc.noaa.gov/oa/climate/research/anomalies/anomalies.html#anomalies.

Natural Sources of Climate Variation

The time scales of natural variations in climate range from cycles of a few years to tens of thousands of years. For example, global temperatures were warmer in the 13th to 15th centuries than in the 16th to 19th centuries.

British Columbia is affected by two major sources of natural short-term variation in the regional climate:

- The Pacific Decadal Oscillation (PDO) is a little understood natural cycling of warm and cool phases in the sea surface temperatures of the Pacific Ocean. The PDO appears to affect the BC climate over a 50- to 60-year cycle (Moore et al. 2002), spending roughly 20 to 30 years in each phase. In British Columbia, the warm phase of the PDO is generally associated with above-average air and ocean surface temperatures and below-average springtime snow pack.
- The El Niño Southern Oscillation (ENSO) phenomenon is related to shifts in tropical air pressure that change temperature and precipitation patterns along the West Coast every few years. For British Columbia an El Niño event generally means a warmer

winter with below-average precipitation, while a La Niña event means a cooler winter with above-average precipitation.

The ENSO and PDO can reinforce or weaken each other's effects, making it difficult to discern short-term trends in the climate and to predict future impacts. The strength of ENSO events varied considerably during the last millennium and the ENSO appears to be sensitive to the background climate, but at this time it is not possible to predict how it will respond to global warming (Tudhope and Collins 2003).

Research shows that the Earth is not warming evenly. Some parts, particularly northern latitudes, have been warming more rapidly than equatorial regions. The impact of global climate change may be intensified or moderated regionally as different levels of the atmosphere, land, and oceans respond on different time scales. Worldwide sea surface temperature, for example, has been increasing about half as quickly as temperature over land, and the deeper water of the ocean has been warming even more slowly. Local conditions also modify the impact. Average overnight low temperatures have been increasing about twice as fast as daytime highs, but about half of this effect may be due to urban and other land-use changes, with the rest due to the effect of global temperature changes (Kalnay and Cai 2003).

These sources of natural climate variability confuse and add uncertainty to trends, therefore small changes will probably remain undetectable for many more years. Despite these caveats, where trends are presented in this review, there is a good level of confidence in the direction, if not the absolute size, of the trends. Note that previously reported indicators for the province (e.g., BCMWLAP 2002b) have been updated and in some cases presented differently to display the current understanding of climate trends and impacts.

Impacts of Climate Change

Because of the global scale involved and the complexity of interactions between climate variables, it is not certain how much the global climate will be affected. Global-scale computer climate simulations for the coming century have been developed by climate research centres in Canada, United States, United Kingdom, Germany, Japan, and Australia. Several greenhouse gas emission scenarios prescribed by the United Nations IPCC are modelled by each centre to produce a range of plausible outcomes. At the global scale, over the coming century, the models project that northern high latitudes will experience the greatest warming, particularly in the winter, with an increase in average annual precipitation (IPCC 2001a).

Given the global scale of predicted changes to the climate, it is reasonable to expect that this will significantly affect physical and biological systems, as well as have socio-economic impacts.

Physical Impacts

Projected—and in some cases already observed—changes to global physical processes as a result of atmospheric warming include:

- increasing frequency and severity of extreme weather, such as heat waves, drought, and high-intensity rainfall (Stott et al. 2004);
- changes in the timing of river flow and water volume (e.g., Whitfield et al. 2002);
- shrinking and loss of mountain glaciers and snow packs, which is of particular concern for communities, growers, and hydroelectricity generators that depend on snow melt for their water supply;
- rising sea level, which has increased about 15–20 cm world-wide during the 20th century (see Indicator 4);
- alteration of ocean temperature, salinity, and density, which may in turn affect ocean circulation and productivity. As has been observed in the past (e.g., Rahmstorf 2003), changes in ocean circulation may be triggered as oceans warm.

Biological Impacts

Climate is the major factor controlling the global pattern of ecosystems and distribution of plants and animals. Therefore a changing climate is expected to drive significant changes in ecosystems and biodiversity. For example, a shift in the pattern of river flow would affect any biological processes that are sensitive to the timing and quantity of freshwater input, such as fish migration and spawning. The most sensitive ecosystems, such as high-altitude and high-latitude ecosystems, already show signs of being affected (Gitay et al. 2001).

Impacts on ecosystems may include changes to:

- ecosystem structure, such as the predominant vegetation, species composition, and distribution of age classes;
- ecosystem function, including productivity, nutrient cycling, and water flows;
- distribution of ecosystems within and across the landscape;
- patterns of disturbance, such as fires, insect and disease infestations, and invasion by alien species.

Impacts on species include changes in:

- phenology, which is the timing of flowering, emergence, and migration;
- growth rate, development, and reproduction;
- interactions between species, such as predation, and competition (see text box).

Recent studies have shown that climate change has already begun to affect biodiversity globally. Changes have been observed in the timing of reproduction and migration, species distribution and population sizes, and the frequency and intensity of fires and pest infestations (e.g., Parmesan and Yohe 2003; Root et al. 2003). Although some species may be able to move to more favourable climates or adapt to the changes, it is likely that most will not. For some, their way may be blocked by unfavourable conditions nearby (e.g., mountains, dry lands), while for others the rate of change required will be too great. For example, in the past, it appears that plant species have dispersed about 20 to 200 km per century (Malcolm and Markham 2000), but within 100 years, Canada's boreal forest is expected to be displaced northward by 200 to 1200 km (Dokken et al. 2002).

HOW CLIMATE CHANGE CAN AFFECT OCEAN PRODUCTIVITY

Spring diatom blooms in the ocean signal the start of the seasonal cycle of production on the BC coast. The timing of the blooms is roughly the same every year because the diatoms respond to day length or light intensity. In contrast, the physiology of organisms as diverse as the copepods that feed on diatoms and the salmon that feed on copepods responds to temperature. As spring comes earlier, these organisms may shift their seasonal cycle of development and reproduction to earlier in the year. They are then out of synchrony with the peak production of the diatoms they depend on for food. Such inefficiency in energy transfer between trophic levels already may have altered some marine ecosystems enough to contribute to the decline of fish stocks (Edwards and Richardson 2004).

Socio-economic Impacts

An immediate economic effect of climate change is the cost of dealing with extreme weather events. Such events also have a social cost to people who are displaced or suffer physical injury and property loss. On the coast, the impact of rising sea level coupled with more extreme weather could increase the risk and costs associated with:

- floods in low-lying coastal areas;
- storm damage to waterfront homes, roads, and port facilities, and erosion of the shoreline;
- saltwater intrusion into groundwater aquifers and saline contamination of low-lying agricultural lands.

Communities and industries that depend on fresh water sources affected by climate change (such as snow pack), will need to invest in conservation measures, developing alternative supplies and building infrastructure. Any economic activities that depend on land-based natural resources, such as agriculture, forestry, salmon fisheries, and even tourism, will feel the effects of changing climate. Long-term changes in ocean conditions will affect the human communities and resource industries that depend on the sea.

Climate change also may affect human health and safety by increasing the range of certain diseases (such as malaria) and the risk of heat-related illnesses, such as heat stroke. Globally, societies that are currently experiencing social, economic, and climatic stresses are likely to be both worst affected and least able to adapt. This includes many in the developing world, low-lying islands and coastal regions, and the urban poor (Burchdal and Hare 2004).

INDICATORS

1. Key Indicator: Long-term trends in air temperature

This is a status indicator. It addresses the questions: Has the climate changed in British Columbia? What are the long-term trends in temperature?

Air temperature and precipitation (see Indicator 2) are the two most commonly measured and widely studied climate variables. Trends in annual temperature for 1950–2001 show the direction and rate of change for this period and also provide an indication of conditions likely in the future.

Methodology and Data

Data presented in this indicator were provided by the Climate Research Branch of Environment Canada; data was analyzed by the Aquatic and Atmospheric Division of the Pacific and Yukon Region of Environment Canada.

Temperature records from 58 climate stations in western Canada were analyzed; 36 stations were in British Columbia. These 36 stations cover all four climatic zones in the province (Table 1); the 22 stations outside British Columbia were used to complete temperature contouring along provincial boundaries. Temperature records were limited to the period 1950–2001 because of gaps and lack of data at many stations before 1950. Trends calculated between 1950 and 2001 were adjusted to a 50-year basis.

The daily quality-controlled temperature data in Environment Canada's archives were adjusted to correct for non-climate-related changes such as relocation of stations and instrument changes. The resulting datasets, taken from *www.cccma.bc.ec.gc.ca/hccd/*, are called Adjusted Historical Canadian Climate Data (Vincent and Gullet 1997; Mekis and Hogg 1999).

Annual and seasonal temperature trends were calculated, as were the number of frost-free days. Trends in frost-free days were calculated from daily minimum temperature data. Trends in the annually averaged daily maximum and minimum temperatures and the number of frost-free days are given in Table 2 for 12 BC climate stations.

Table 1. Location of British Columbia climate stations providing data for the air temperature indicator.

Station name	Climatic zone	Station name	Climatic zone
Abbotsford Airport	Pacific	Wistaria	South BC mountains
Aggasiz CDA	Pacific	Barkerville	South BC mountains
Victoria Gonzales Hts	Pacific	Burns Lake CS	South BC mountains
Comox Airport	Pacific	Fort St. James	South BC mountains
Port Hardy Airport	Pacific	Quesnel Airport	South BC mountains
Estevan Point	Pacific	Summerland CDA	South BC mountains
Prince Rupert Airport	Pacific	Cranbrook Airport	South BC mountains
Sandspit Airport	Pacific	Kamloops Airport	South BC mountains
Bella Coola	Pacific	Golden Airport	South BC mountains
Cape St. James	Pacific	Prince George Airport	South BC mountains
Stewart Airport	Pacific	Kaslo	South BC mountains
Quatsino	Pacific	Warfield	South BC mountains
Victoria Airport	Pacific	Vavenby	South BC mountains
Dease Lake	North BC mountains	Revelstoke	South BC mountains
Fort St. John	Northwestern forest	Princeton Airport	South BC mountains
Fort Nelson	Northwestern forest	Vernon CS	South BC mountains
Smithers Airport	South BC mountains	Castlegar Airport	South BC mountains
Tatlayoko Lake	South BC mountains	Creston	South BC mountains

Source: Climate Research Branch, Environment Canada.

Trends were calculated using the Microsoft Excel template MAKESENS developed by the Finnish Meteorological Institute (Salmi et al. 2002) (available at *www.fmi.fi/organization/contacts_25.html*). The MAKESENS software uses the nonparametric Sen's linear estimate for the slope of the trend line and the nonparametric Mann-Kendall test to evaluate whether that slope is statistically different from zero (no trend). Before trend calculations, the data were adjusted for autocorrelation using the prewhitening method of Wang and Swail (2001). This is a statistical correction method applied to data so that the subsequent analysis avoids overestimating the significance of a trend.

Temperature trends were mapped onto the provincial map with Surfer® (Golden Software) contouring and mapping software (Figure 2).

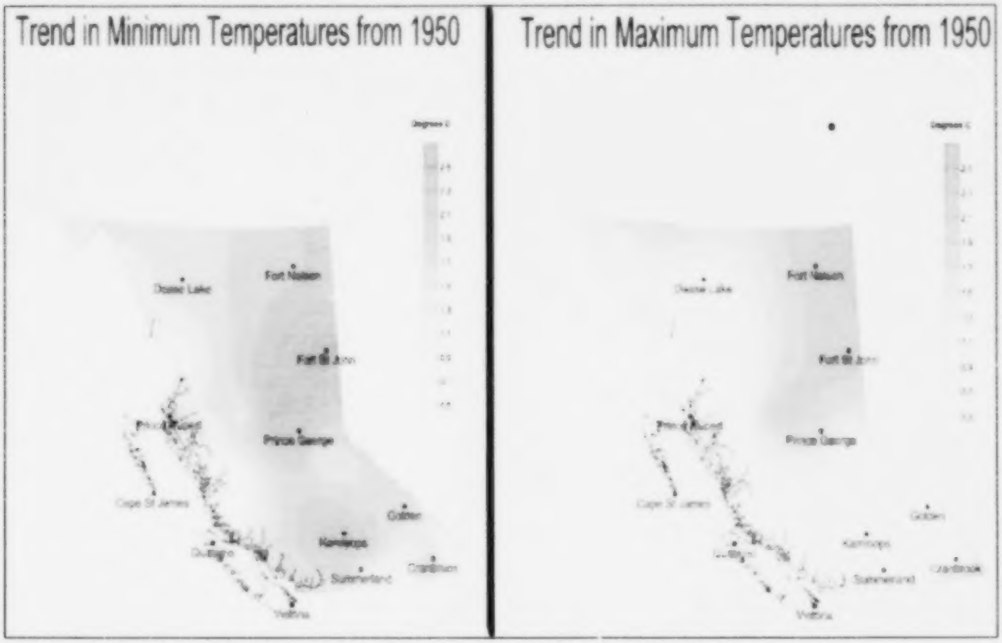
Table 2. Fifty-year trends in the annually averaged daily maximum (Tmax) and minimum (Tmin) temperatures and the increase in the number of frost-free days for 12 of the climate stations used in the analysis for Figure 2.

Station name	Element	Winter	Spring	Summer	Autumn	Annual
Victoria Airport	Tmin (°C)	1.0	1.8*	1.0*	0.5	0.9
	Tmax (°C)	1.0	1.3*	1.0*	0.8	1.0*
	Frost-free days (days)					21.8
Quatsino	Tmin (°C)	1.9	2.0*	0.7	0.8	1.0
	Tmax (°C)	0.7	5.4*	0.8	0.2	0.47
	Frost-free days (days)					21.3
Cape St James	Tmin (°C)	1.4	1.6*	0.5	0.5	0.9
	Tmax (°C)	0.6	0.8	0.8	0.6	0.8
	Frost-free days (days)					15.6
Prince Rupert Airport	Tmin (°C)	2.1	2.1*	1.2	1.0	1.6*
	Tmax (°C)	1.2	1.2*	0.4	0.1	0.7
	Frost-free days (days)					46.3*
Prince George Airport	Tmin (°C)	4.0	2.8*	2.0*	0.7	2.2*
	Tmax (°C)	1.6	2.2*	0.8	0.5	1.6*
	Frost-free days (days)					21.3*
Summerland	Tmin (°C)	1.7	1.7*	1.2*	0.9	1.4
	Tmax (°C)	0.9	1.3*	0.5	0.8	0.7
	Frost-free days (days)					16.1
Cranbrook Airport	Tmin (°C)	2.1	2.4*	1.2	1.1	1.9
	Tmax (°C)	0.8	2.3*	0.6	1.3	1.2
	Frost-free days (days)					15.6
Kamloops Airport	Tmin (°C)	3.0	2.5*	2.6*	1.0	2.5*
	Tmax (°C)	2.2	2.4*	0.2	0.1	1.0
	Frost-free days (days)					34.8*
Golden	Tmin (°C)	2.2	2.5*	1.5*	1.0	1.8*
	Tmax (°C)	1.6	1.1	0.7	1.2	0.7
	Frost-free days (days)					18.2*
Fort St John	Tmin (°C)	5.3*	3.4*	0.8	0.6	2.4*
	Tmax (°C)	4.5*	2.9*	0.2	0.1	2.1*
	Frost-free days (days)					18.2*
Dease Lake	Tmin (°C)	3.7	1.9*	0.7	0.3	1.7*
	Tmax (°C)	3.2	2.4*	0.3	–0.5	1.0
	Frost-free days (days)					10.4
Fort Nelson Airport	Tmin (°C)	3.9*	2.5*	0.6	0.4	1.8*
	Tmax (°C)	3.9*	3.5*	0.4	0.3	2.1*
	Frost-free days (days)					12.5*

Source: Environment Canada: *www.ecoinfo.ec.gc.ca/env_ind/region/climate/climate_e.cfm*.

Note: Asterisks indicate statistical significance. Probability or chance that there is no trend (α): < 5%.

Figure 2. Fifty-year trends in daily minimum and daily maximum temperatures shown as change in degrees Celsius since 1950.


Trend in Minimum Temperatures from 1950
Trend in Maximum Temperatures from 1950
Degrees C
Dease Lake
Fort Nelson
Fort St. John
Prince Rupert
Prince George
Cape St James
Kamloops
Golden
Summerland
Cranbrook
Victoria

Source: Environment Canada *www.ecoinfo.ec.gc.ca/env_ind/region/climate/climate_e.cfm.*

Note: The graphic shows generalized temperature changes for the region but is not meant to represent accurate temperature changes for specific areas or locations.

Interpretation

Data from BC climate stations (Table 2) show rising temperatures and fewer days with frost over a 50-year period at many stations in the province. The pattern was generally similar at the other 24 BC monitoring stations not displayed in Table 2. Most of British Columbia appears to be experiencing a pattern of warming consistent with what has been observed globally. No station shows a decrease in temperature over the period 1950–2001, and analysis showed that, averaged over the whole year, air temperature has been rising throughout the province. Winter and spring temperatures in British Columbia appear to be rising more rapidly than summer temperatures, which is the same trend other researchers have found over a similar period, 1950–1998 (Zhang et al. 2000).

The overnight minimum air temperature has been increasing faster than the daytime maximum, with most of British Columbia showing higher annual minimum temperatures (Figure 2). This is creating a climate with a narrower daily temperature range, a longer growing season, and fewer days of frost each year. The temperature increases have been least pronounced on the coast and more pronounced in northeastern British Columbia and in the Okanagan region. This pattern is consistent with the output of climate models.

2. Secondary Indicator: Long-term trends in precipitation

This is a status indicator. It addresses the questions: Are precipitation patterns changing? Is climate change affecting precipitation patterns in British Columbia?

Precipitation (along with temperature) is one of the two most important variables affecting terrestrial and coastal ecosystems.

Methodology and Data

Daily precipitation data were obtained from the Climate Research Branch of Environment Canada.

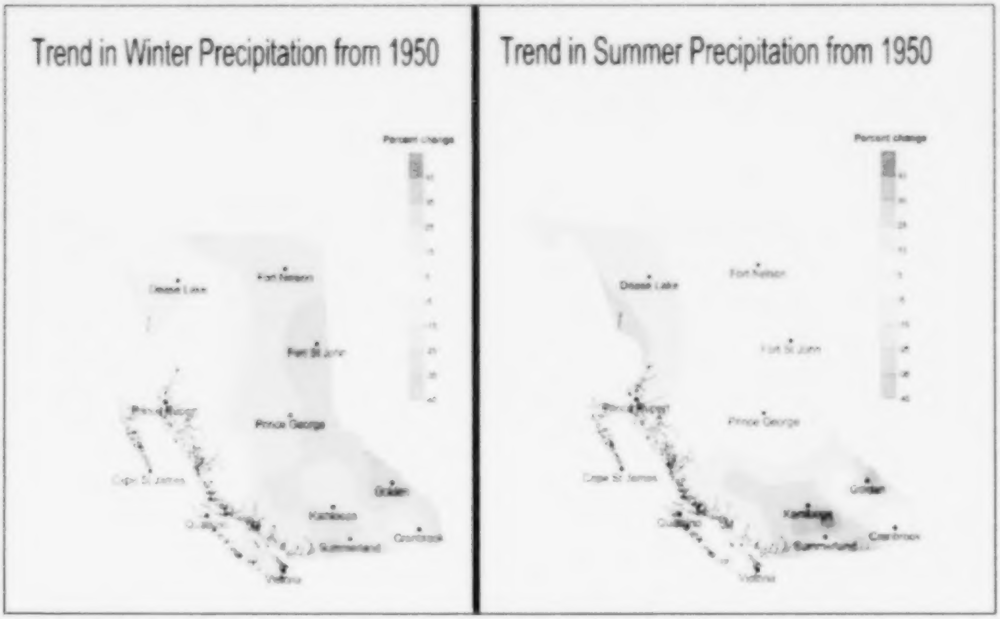
The analysis reported here used data from 40 climate monitoring stations in British Columbia (listed in Table 3). An additional seven stations in Alberta, Yukon, and Northwest Territories were used to aid contouring near the provincial borders. The trend analysis was limited to the period 1950–2001 because of gaps and a general lack of data at many stations before the 1950s. The quality-controlled precipitation data in Environment Canada's archives were adjusted to correct for non-climate-related changes, such as relocation of stations and instrument changes. The resulting datasets taken from *www.cccma.bc.ec.gc.ca/hccd/* are called Adjusted Historical Canadian Climate Data (AHCCD: Vincent and Gullet 1997; Mekis and Hogg 1999).

Table 3. Locations of the climate monitoring stations in British Columbia used in the precipitation analysis.

Agassiz
Barkerville
Bella Coola
Blue River Airport
Cape St. James
Comox Airport
Cranbrook Airport
Creston
Dease Lake
Estevan Point
Fort Nelson Airport
Fort St. James
Fort St. John Airport
Golden Airport
Grand Forks
Kamloops Airport
Kaslo
Kelowna Airport
Langara
McInnes Island
Oliver STP
Port Hardy Airport
Prince George Airport
Prince Rupert Airport
Princeton Airport
Quatsino
Quesnel Airport
Revelstoke Airport
Sandspit Airport
Smithers Airport
Stewart Airport
Summerland CDA
Tatlayoko Lake
Terrace Airport
Vancouver Airport
Vavenby
Vernon CS
Victoria Airport
Warfield
Wistaria

Precipitation trends were mapped onto the provincial map with Surfer® (Golden Software) contouring and mapping software (Figure 3).

Figure 3. Fifty-year trends in summer and winter precipitation, shown as percentage change since 1950.


Trend in Winter Precipitation from 1950
Percent change
Dease Lake
Fort Nelson
Fort St John
Prince Rupert
Prince George
Cape St James
Golden
Kamloops
Quatsino
Summerland
Cranbrook
Victoria
Trend in Summer Precipitation from 1950
Percent change
Dease Lake
Fort Nelson
Fort St John
Prince Rupert
Prince George
Cape St James
Golden
Kamloops
Quatsino
Summerland
Cranbrook
Victoria

Source: Environment Canada *www.ecoinfo.ec.gc.ca/env_ind/region/climate/climate_e.cfm.*

Note: The graphic shows generalized precipitation changes for the region, but is not meant to represent accurate changes in amounts for specific areas or locations.

Interpretation

Total annual precipitation (1950–2001) has increased in several regions of British Columbia, with the Okanagan and North Coast regions showing the largest increases. Eastern British Columbia has been receiving less precipitation on an annual basis. The annual trends mask a more significant shift in seasonal patterns: with the exception of the North Coast, winter throughout most of the province has become drier (see Figure 3). Except for the Rocky Mountains, spring and summer have become wetter.

As shown in Table 4, most of British Columbia is experiencing drier winters, but wetter spring and summer conditions.

Table 4. Percentage change in precipitation over 50 years for 12 of the climate stations used in the analysis for Figure 3.

	Trend (%)				
Station name	Winter	Spring	Summer	Autumn	Annual
Victoria Int'l A	−16	13	−4	−3	−3
Quatsino	−1	22	31	14	13
Cape St. James	6	−4	−1	3	13
Prince Rupert A	3	2	11	31*	18*
Prince George A	−20	18	0	−3	−4
Summerland	−18	52*	21	4	19
Cranbrook A	−79*	20	0	−28	−28
Kamloops A	−25	46*	34	31	21*
Golden	−42*	32	42*	9	2
Fort St. John	−33	−12	−2	12	−8
Dease Lake	24	20	18	8	27*
Fort Nelson A	−21	−5	3	22	5

Source: Environment Canada *www.ecoinfo.ec.gc.ca/env_ind/region/climate/climate_e.cfm.*

Note: Asterisks indicate statistical significance. Probability, or chance, that there is no trend (α): <5%.

Overall patterns of temperature and precipitation have not changed in lockstep over most of the province. A few patterns that do appear for the province are:

- South Coast: spring has become warmer, but average precipitation has not changed significantly since 1950.
- North Coast: night-time temperatures are warmer in the spring and the region has become wetter over the annual cycle.
- Rocky Mountains and Northern Interior Plains: summers are warmer, with not much change in annual precipitation. Winters have become warmer and drier.
- Okanagan: springs are warmer and wetter.

3. *Secondary Indicator: Coastal ocean temperature*

This is a status indicator. It addresses the question: Is climate change affecting ocean temperature along the BC coast?

The temperature of the ocean affects coastal weather and climate. Ocean temperature is influenced by air temperature and, in turn, ocean temperature influences air temperature. Ocean temperature, with salinity, affects the survival, growth, and reproductive success of marine life and the productivity and composition of marine ecosystems.

Methodology and Data

The naturally large variability in ocean temperatures, due to cycles such as the PDO and ENSO, means that a very long series of observations is needed to detect underlying long-term trends. The longest water temperature series for the BC coast comes from daily surface observations taken at eight lighthouses and at the Pacific Biological Station in Departure Bay (Table 5).

Daily sampling at lighthouse stations is done at high tide only during the daytime. Because high tide occurs about 50 minutes later each day, temperatures are not taken at the same time each day. When the daytime high tide approaches 6 p.m., the sampling cycle starts again at 6 a.m. Because afternoon temperatures tend to be higher, this sampling protocol creates a 14-day signal as an artefact. The temperature of the water is measured with a thermometer, generally with an accuracy of about 0.2°C.

Daily and monthly mean data were obtained from the Fisheries and Oceans Canada website (*www-sci.pac.dfo-mpo.gc.ca/osap/data*). The annual means reported here have been calculated from the monthly mean data for only those years where monthly mean values are available for all 12 months.

Table 5. Location of the stations providing data for the ocean temperature indicator.

Station	Latitude (°N)	Longitude (°W)	Year of first observation	Area
Langara Island	54°09'	133°02'	1936	North Coast
McInnes Island	52°10'	128°26'	1954	Central Coast
Pine Island	50°35	127°26	1937	Central Coast
Kains Island	50°16'	127°01'	1935	West Coast Vancouver Island
Nootka Point	49°14'	126°20'	1934	West Coast Vancouver Island
Amphitrite Point	48°33'	125°19'	1934	West Coast Vancouver Island
Departure Bay	49°08'	123°34'	1914	East Coast Vancouver Island
Entrance Island	49°08'	123°29'	1936	Strait of Georgia
Race Rocks	48°11'	123°19'	1921	Juan de Fuca Strait

The annual maximum and minimum sea-surface temperatures were determined from daily observations. Because there are gaps in the observations in some years, a maximum or minimum reading was included in this analysis only if observations were available for every day within seven days before or after the maximum or minimum and if the extreme reading occurred at a likely time of year. Extraordinary maximum and minimum records were used only when other observations around the same time indicated that the extreme values were probably real and not the result of an error. For extreme values likely to occur during the winter, the data are included in a given "year" beginning October 1 through to September 30 of the next year.

Trends were determined using the Microsoft Excel template MAKESENS. This template uses a nonparametric Mann-Kendall test to assess the probability that there is a trend statistically different from zero, and a nonparametric Sen's linear estimate for the slope of the trend line. Most series had significant autocorrelations at time lags of one and two sampling intervals, so the calculations were prewhitened using the procedure described in Wang and Swail (2001) until the trend and first-lag autocorrelation changed by less than 5% from one iteration to the next.

Note that other methods for computing trends yield slightly different results, both in terms of confidence intervals and the number of datasets showing significant positive trends. Regardless of the computational method, however, there is agreement in the overall finding that there are detectable and significant increases in sea-surface temperature.

Interpretation

Over the last 50 years, the ocean has become warmer all along the BC coast, as indicated by trends in the annual mean sea surface temperatures (Figure 4). Not all of the nine stations showed statistically significant trends, but for the five that do, all trends are positive. The annual mean temperatures for at least one station in each major coastal area had a positive trend that was significantly different from zero at the 95% confidence level. The largest and most significant increase was a warming of 0.9°C in 50 years for Langara Island, at the northwest tip of the Queen Charlotte Islands. The second largest change, 0.8°C in 50 years, was for Entrance Island, in the central Strait of Georgia.

More than half of the coastal stations show a significant increase in mean annual sea-surface temperature (Table 6). Fewer stations show significant trends in the annual maximum and minimum temperatures (Tables 7 and 8). The extreme values are more variable than the annual means, as shown by the greater standard deviations. The variations in annual mean sea-surface temperatures from year to year were only about 0.5ºC at any of the nine stations. This compares with an average annual range between minimum and maximum daily temperatures of 5 to16ºC.

Three of the nine stations show statistically significant increases in either the annual maximum or annual minimum temperature. The most statistically significant trend is an increase in annual maximum temperature at Entrance Island, 1.7°C in 50 years. The largest increase in the annual minimum is at Langara Island, 1.7°C in 50 years, but this is only weakly significant. These two stations also showed the largest trends in annual mean temperatures. It appears that the increase in the annual mean at Langara may reflect warmer winter waters, whereas the increase at Entrance Island reflects increased summer warming in the Strait of Georgia.

The water around Langara Island, at the extreme northwest point on the BC coast, is about 1.5°C colder than that around Amphitrite Point, on the southwest coast of Vancouver Island, for both annual mean and average annual extremes. At the present rate of increase, temperatures at Langara Island would resemble current conditions at Amphitrite Point in less than a hundred years.

Table 6. Mean annual sea-surface temperature at nine stations on the BC coast.

Station	First year	Latest year	Years used	Annual mean (°C)	Standard deviation (°C)	Trend (°C/50 years)
Langara Island	1941	2003	61	8.8	0.52	0.94*
McInnes Island	1955	2003	46	9.6	0.48	0.65
Pine Island	1937	2003	65	8.7	0.51	0.71*
Kains Island	1935	2003	68	10.2	0.55	0.43
Nootka Point	1935	2003	32	10.9	0.51	0.55
Amphitrite Point	1935	2003	68	10.4	0.52	0.50*
Departure Bay	1915	2003	68	11.1	0.50	0.29
Entrance Island	1937	2002	65	11.2	0.51	0.82*
Race Rocks	1922	2003	64	9.1	0.44	0.39*

Source: Fisheries and Oceans Canada, *www-sci.pac.dfo-mpo.gc.ca/osap/data*.

Note: Asterisks indicate statistical significance. Probability or chance that there is no trend (α): <5%.

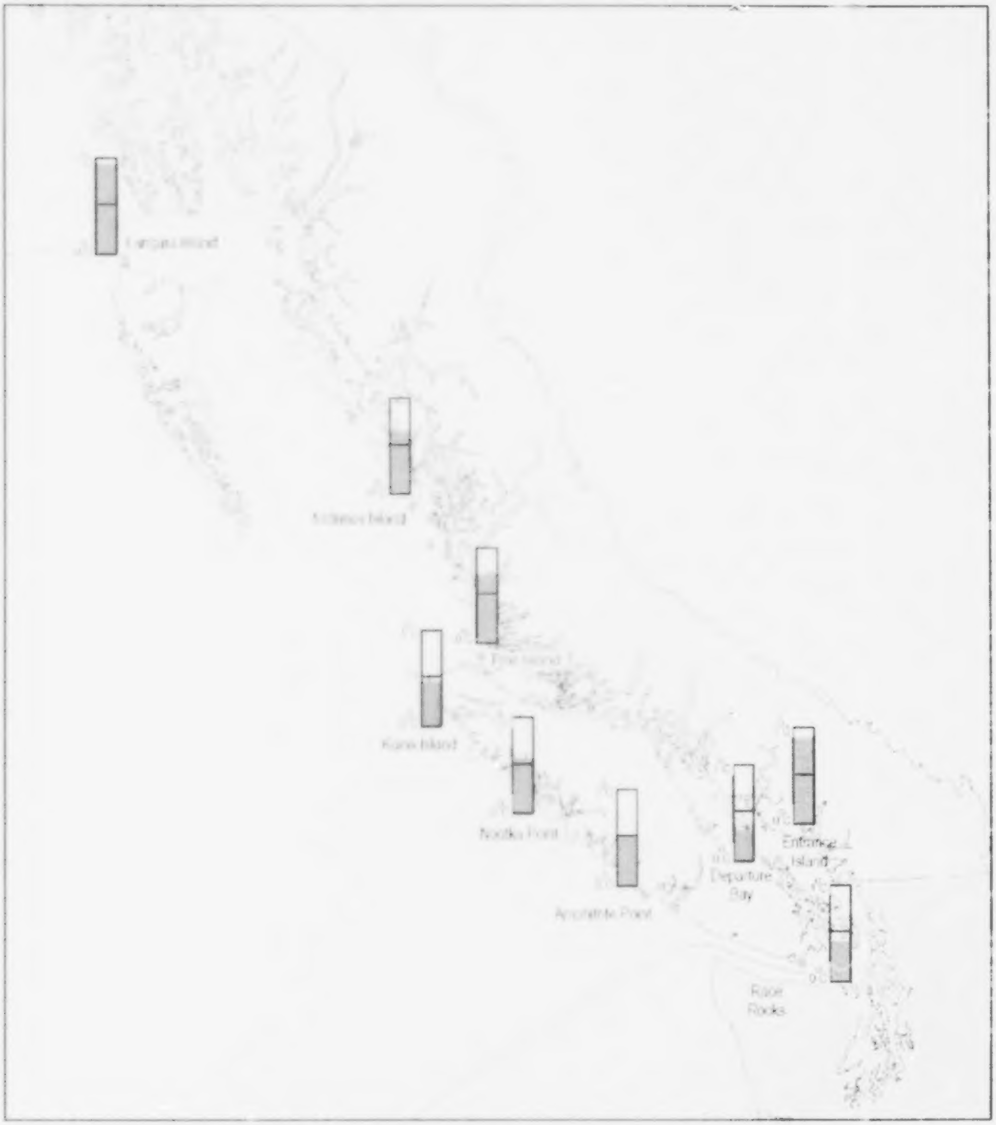
Table 7. Mean annual maximum sea-surface temperatures at nine stations on the BC coast.

Station	First year	Latest year	Years used	Mean annual maximum (°C)	Standard deviation (°C)	Trend (°C/50 years)
Langara Island	1940	2004	48	13.8	1.00	0.70
McInnes Island	1954	2004	43	15.2	0.79	0.81
Pine Island	1937	2003	65	11.6	0.82	0.34
Kains Island	1935	2003	64	15.5	0.86	−0.07
Nootka Point	1938	2004	32	18.4	0.97	1.13*
Amphitrite Point	1935	2002	58	15.2	1.06	0.60
Departure Bay	1915	2004	66	20.8	1.17	0.32
Entrance Island	1936	2004	68	20.6	1.30	1.69*
Race Rocks	1921	2004	79	12.5	0.91	0.30

Source: Fisheries and Oceans Canada, *www-sci.pac.dfo-mpo.gc.ca/osap/data*.

Note: Asterisks indicate statistical significance. Probability or chance that there is no trend (α): <5%.

Figure 4. Rates of changes in sea-surface temperature (°C/50 years) at nine lighthouse stations on the BC coast.


Langara Island
McInnes Island
Pine Island
Kains Island
Nootka Point
Amphitrite Point
Departure Bay
Entrance Island
Race Rocks

Source: Fisheries and Oceans Canada *www.pac.dfo-mpo.gc.ca/sci/osap/data*.

Note: Red bars indicate values that are statistically significant at <0.5%.

Table 8. Mean annual minimum sea-surface temperature at nine stations on the BC coast.

Station	First year	Latest year	Years used	Mean annual minimum (°C)	Standard deviation (°C)	Trend (°C/50 years)
Langara Island	1937	2004	47	4.8	1.22	1.72
McInnes Island	1955	2002	45	5.4	0.84	0.13
Pine Island	1939	2004	62	6.7	0.75	0.68*
Kains Island	1935	2004	64	6.2	1.09	0.57
Nootka Point	1937	2004	33	4.8	1.22	–0.06
Amphitrite Point	1936	2004	52	5.9	1.06	0.14
Departure Bay	1915	2003	65	4.0	1.73	0.80
Entrance Island	1937	2004	64	5.1	1.24	–0.26
Race Rocks	1922	2003	70	6.4	0.88	0.51

Source: Fisheries and Oceans Canada, *www-sci.pac.dfo-mpo.gc.ca/osap/data*.

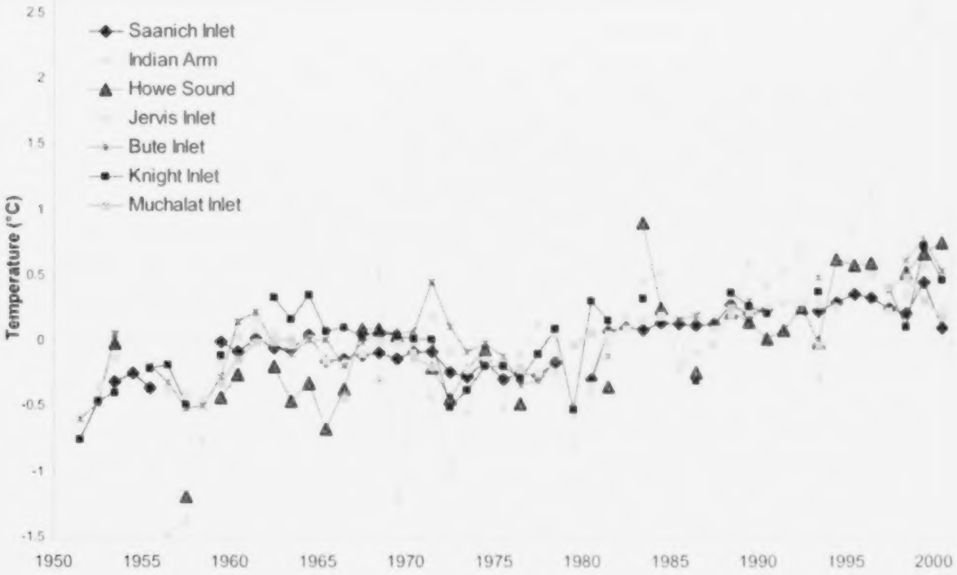
Note: Asterisks indicate statistical significance. Probability or chance that there is no trend (α): <5%.

Supplementary Information: Deep-Water Warming

A warming trend in the ocean along the southern BC coast also shows in the deeper waters of five inlets on the mainland coast and two on Vancouver Island (Figure 5). Consistent with the temperature trends shown in the sea-surface indicator, all seven inlets showed a warming of 0.5 to 1.0°C over the last 50 years.

Note that the graph displays temperature anomalies that depart from the average (set as 0°C) over the period for each time series. Bottom water temperatures in the inlets generally range from 6.5 to 8.5°C.

Figure 5. Deep-water temperature anomalies for inlets in southern British Columbia. Zero represents the average over the period for each time series.



Source: Ocean Science and Productivity Group, Institute of Ocean Sciences, Fisheries and Oceans Canada *www-sci.pac.dfo-mpo.gc.ca/osap/projects/bcinlets/intro_e.htm*.

Note: Observations were collected from at least 200 m below the surface, so they are not subject to the same daily and tidal temperature variation as surface waters. Sampling was less frequent than shore station observations, typically once per year, with frequent gaps of several years between sampling.

4. Secondary Indicator: Sea level on the British Columbia coast

This is a status indicator. It addresses the questions: Is sea level rising along the BC coast? How will climate change affect shore zones in British Columbia?

One widely publicized consequence of global warming is a projected rise in sea level. Rising sea levels are due partly to an increase in the volume of water as it warms and expands and partly to the increased flow of freshwater from land as melting ice adds to the total volume of water in the oceans (Miller and Douglas 2004). Combined with extreme weather, a rise in sea level may result in more frequent flooding and salt contamination of low lying areas, as well as storm damage to areas and structures previously above high water.

Methodology and Data

Water levels along the British Columbia coast are recorded by tide gauges at stations maintained by the Canadian Hydrographic Service and the Water Survey of Canada. Some recording stations have records going back to 1909, although there are gaps for some years. Water level observations consist of short averages of the position of a float in a vertical tube or stilling well. The stilling well is connected to the nearby ocean by a small hole or tube, removing most of the effect of short-period disturbances like wind-generated waves or vessel wakes. Early gauges recorded on paper charts were read manually to provide values hourly and at high and low water. More recent equipment electronically records a 1-minute average every minute. The vertical position of the gauge is referred to nearby geodetic benchmarks. Zero is set to correspond to nautical chart datum, which has traditionally been the level of lowest normal tides.

For this indicator, climate trends were examined using data from four tide gauge stations with long records that were considered broadly representative of three of the four coastal oceanic regions (Table 9). No data series was long enough to detect trends for the fourth oceanic region, the outer coast of the Queen Charlotte Islands.

Table 9. Annual change in mean sea level since first year of records at four locations on the BC coast.

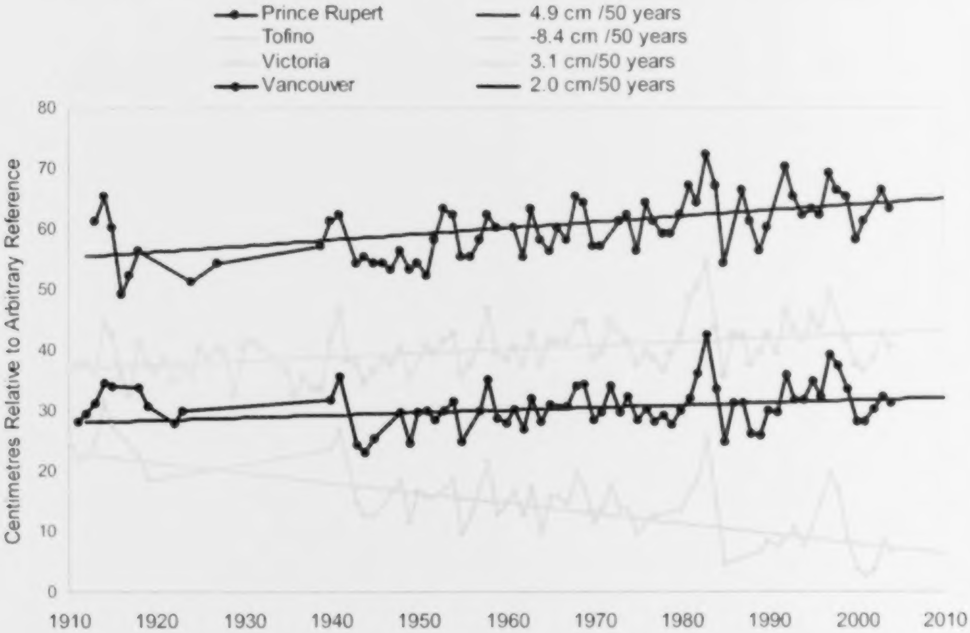
Station	First full year	Latest full year	Years used	Annual mean (cm)	Standard deviation (cm)	Trend (cm/50 years)	Chance of no trend
Prince Rupert	1913	2004	68	384.7	4.9	4.9	<0.05
Tofino	1910	2004	60	213.5	6.3	–8.4	<0.001
Vancouver	1911	2004	69	305.7	4.8	2.0	>0.1
Victoria	1910	2003	90	187.4	4.0	3.1	<0.01

Source: Marine Environmental Data Service, Fisheries and Oceans Canada.

Sea level data were obtained from the Marine Environmental Data Service (MEDS) of Fisheries and Oceans Canada. Trends were fitted to annual mean values to assess mean sea level rise. The means were based on all available data, including observations read manually from chart recordings not presently available in digital format. Except for Victoria, each station had some years missing. Even the most complete years were missing data for a few days. The data for Vancouver had not been adjusted for changes to the datum (the zero point of the scale) for the years between 1910 and 1957. The annual means were recalculated for Vancouver for those years, using the values corrected for the datum change, by adding 61 cm from 1910 through 1948 and 12 cm from 1949 through 1957.

Trends were determined using the Microsoft Excel template MAKESENS. This template uses Sen's linear estimate for the slope of the trend line and uses a non-parametric Mann-Kendall test to assess the probability that there is a trend statistically significant from zero. Most series had significant autocorrelations at time lags of one and two sampling intervals (years), so the calculations were iterated using the procedure described in Wang and Swail (2001) until the trend and first-lag autocorrelation changed by less than 5% from one iteration to the next. Removing the effects of autocorrelation provides a statistically reliable estimate of the trend. To display the trends on one graph, the data were rescaled by adding a unique elevation to all the data for each station. Results are shown in Figure 6.

Figure 6. Changes in annual mean sea level at four locations on the BC coast.



Source: Marine Environmental Data Service, Fisheries and Oceans Canada.

Note: Trend lines were fitted using MAKESENS.

Interpretation

The analysis of sea level records shows that relative sea levels have been rising at Prince Rupert, Vancouver, and Victoria, but falling at Tofino. Differences between stations are explained on the basis of geological processes, which cause vertical movements of the shoreline that partly or completely cancel the effects of an expanding ocean. The landmass of British Columbia is rebounding vertically after the massive ice sheet melted approximately 10,000 years ago—a process called isostatic rebound. The rate of rebound along the coast is estimated to be 0 to 4 mm per year. Also, the western edge of the North American continent is sliding over adjacent oceanic plates, resulting in crustal uplift estimated to be as high as 4 mm per year along the southwest coast of Vancouver Island near Tofino (Peltier 1996). The effect is that the measured water level drops as the coast (and the zero datum point) rises.

The level of water against the BC coast also varies cyclically. The largest effects (with typical range of variation in parentheses) recorded by tide gauges (J. Garrett, pers. comm.) are associated with:

- tides, at periods as long as 19 years and as short as 4 cycles per day (5 m);
- variation in the large-scale ocean circulation, such as ENSO (30 cm);
- variation in atmospheric pressure (30 cm);
- variation in winds or "storm surges" (less than 1 m in BC waters);
- seasonal variations in ocean temperature and salinity due to variations in freshwater discharge from coastal rivers (less than 10 cm).

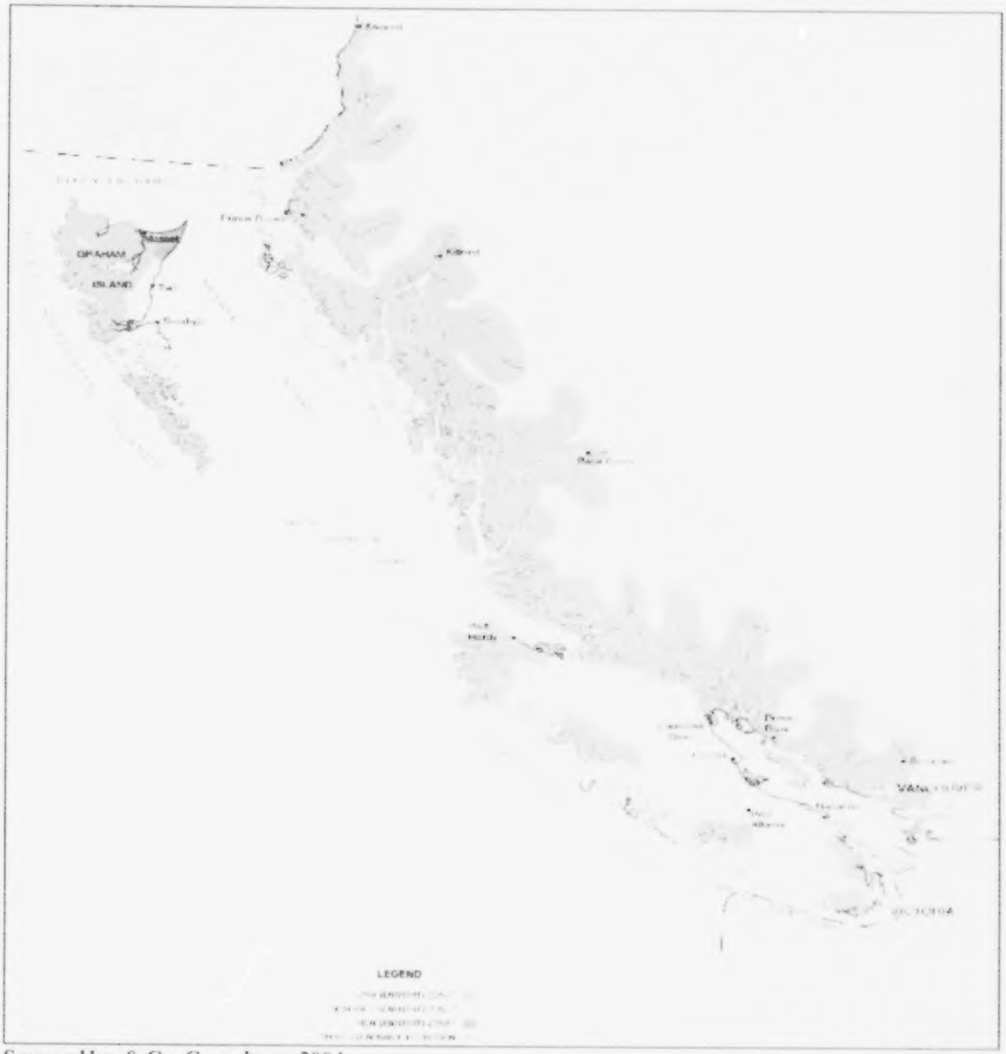
The magnitude of these effects means that interannual changes in mean sea level can be greater than the cumulative rise over the entire period. From 1980 to 1983, mean sea level rose by 12 cm in Victoria and Vancouver and by 10 cm in Prince Rupert. However, from 1983 to 1985 it declined by 19 cm in Victoria, 17 cm in Vancouver, and 18 cm in Prince Rupert. Both of these changes were associated with an ENSO event. Nevertheless, at all stations except Tofino, continuing the long-term trend in sea level would result in mean and extreme relative sea levels higher than have yet been observed. At Tofino, it is expected that relative sea level will continue to fall, exposing more of the shoreline until the next major subduction zone earthquake causes coastal land to drop.

In the long term, global mean sea level is projected to rise by 0.09–0.88 m between 1990 and 2100 (IPCC 2001b). The rate and magnitude of sea level rise are not uniform over the globe; they differ with ocean basin, reflecting variations in ocean heating and the way in which ocean currents redistribute the heat and water mass. One indication of what might be happening in the northeast Pacific Ocean is provided by measurements of the expansion of the upper 1000 m of the ocean water column due to warming and decreased salt content between 1956 and 1986. This suggests a contribution of 1.1 mm per year to the overall rate of sea level rise (Thomson and Tabata 1989).

Supplementary Information: Sensitivity of the BC Coast to Sea Level Rise

Rising sea level is a practical concern on the BC coast. Parts of the Lower Mainland coast are particularly vulnerable to erosion and flooding under extreme weather conditions (Figure 7), but areas with rocky, relatively steep-sided fiords are not considered sensitive to rising sea levels, flooding, or erosion from extreme wave action. Sections of British Columbia's coast that would be the most sensitive to rising sea levels include the Fraser Delta and the Naikoon area of the Queen Charlotte Islands, which is presently eroding. These areas are vulnerable to flooding and erosion from waves, which could reach into areas not normally washed by the sea. In these areas, changing weather patterns may give rise to more frequent occurrences of unusually high or low sea levels, resulting in flooding of low lying areas or exposure of normally submerged areas (Beckman et al. 1997).

Figure 7. Sensitivity of the BC coastline to sea level rise and erosion.


GRAHAM
ISLAND
Masset
VANCOUVER
VICTORIA
LEGEND

Source: Hay & Co. Consultants 2004.

WHAT IS HAPPENING IN THE ENVIRONMENT?

As shown by the trends in the indicators presented in this paper, the climate in British Columbia has changed in the last half-century. Average air temperature has become higher in many areas. Overnight lows have been increasing faster than daytime highs, resulting in fewer nights with frost. Air temperature on the coast has been less affected than in the interior and northeast of the province. Springtime temperatures are generally warmer over the whole province. With the exception of the north coast, winters have become dryer throughout most of the province. Although this coincides with a period in which the PDO shifted from its cool phase to a warm one in the late 1970s, the method of analysis for temperature and precipitation trends used in these indicators was designed to remove bias in the records due to such cyclic influences.

Sea surface temperature has risen over the entire coast, with the North Coast and the central Strait of Georgia showing the largest increases. Deep-water temperatures have also increased in five inlets on the South Coast. With the exception of areas of the coast being pushed up due to geological processes, relative sea level has risen along parts of the BC coast over the century.

The direction and spatial pattern of the climate changes reported for British Columbia are consistent with broader trends in North America and the type of changes predicted by climate models for the region. Table 10 presents the range of predictions from eight global modelling centres for the north and south coast of the province as well as the central and northeastern interior. The analysis shows that by 2050, there is significant likelihood of warming in both winter and summer for coastal and interior regions. There is less agreement among the model outcomes for changes in precipitation, with some predicting drier winters on the south coast and others wetter winters. Generally the model results show that for much of the province, winters will likely become wetter and summers drier.

Table 10. Range of predicted changes in winter and summer temperature and precipitation by 2050 for four regions in British Columbia.

BC location	Temperature change by 2050 (°C)		Precipitation change by 2050 (%)	
	Winter	Summer	Winter	Summer
North Coast	0 to 3.5 warmer	1.5 to 3 warmer	0 to 25 wetter	−25 to +5
South Coast	0 to 3 warmer	1.5 to 5 warmer	−10 to + 25	−50 to 0 drier
Central Interior	0.5 to 4.5 warmer	1.5 to 3.5 warmer	0 to 30 wetter	−20 to 0 drier
Northeast Interior	0 to 6 warmer	1.5 to 3 warmer	5 to 30 wetter	−15 to +20

Source: From data in the Canadian Institute for Climate Studies, University of Victoria (*www.cics.uvic.ca*) study of model results from eight global climate modelling centres. A total of 25 model runs using the eight models were used to determine the range of values under different IPCC emission scenarios (Nakicenovic and Swart 2000).

Note: Values shown are net changes for 2050 relative to the base period, defined as average temperature and precipitation for summers and winters during the period 1961–1990.

Global climate models are considered low resolution because they employ grids that are generally 400 km across at Canadian latitudes, and thus are not well suited for detailed regional assessment. One method of increasing regional detail is to run higher resolution regional climate models over a smaller area, nested inside the global models. A team of researchers at Université du Québec à Montréal and Ouranos Inc. are developing and testing the Canadian Regional Climate Model (CRCM) that provides 45-km resolution. Some early results can be found at *www.cccma.bc.ec.gc.ca* and a description of the methodology is available at *www.mrcc.uqam.ca*. Other regional climate models are being developed and will be run over North America in the coming years (see *www.narccap.ucar.edu/*). When a suite of these models is available covering British Columbia, it will be possible to develop more detailed impact assessments.

WHY IS CLIMATE CHANGE HAPPENING?

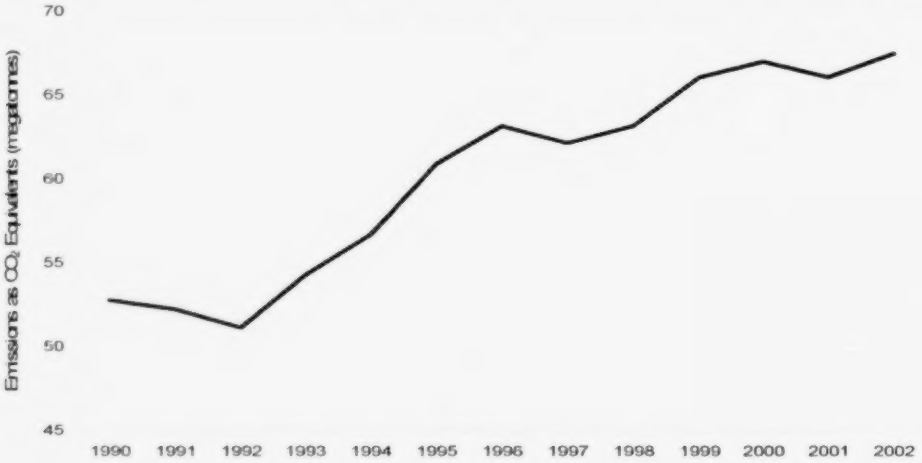
Carbon dioxide in the world's atmosphere has risen from its pre-industrial concentration of about 280 parts per million (ppm) to about 375 ppm today. Along with increasing concentrations of other greenhouse gases, this rise is causing the atmosphere to trap more heat. Although water vapour is a greenhouse gas, and there are natural sources of other greenhouse gases, most climate scientists agree that emissions of CO_2 due to fossil fuel burning are, and will continue to be, the dominant influence causing atmospheric CO_2 concentrations to rise during the 21st century (e.g., IPCC 2001b). This means that human activity is largely responsible for the increase in the gases causing rising air temperature. Climate models show that increasing concentrations of CO_2 could raise the global average surface temperature an additional 1.4–5.8°C by 2100 (Houghton et al. 2001).

CO_2 EQUIVALENTS

Different greenhouse gases are more or less efficient at trapping solar energy. Therefore, to enable comparisons, greenhouse gases are described in terms of the amount of CO_2 (in metric tonnes) that would cause the same effect as an amount or mixture of other greenhouse gases. This measure is then used to compare the emissions of different greenhouse gases based on their global warming potential.

From 1990 to 2002, British Columbia's greenhouse gas emissions rose an average 2.1% per year. Emissions rose from 51.2 million tonnes of CO_2 equivalents in 1992 to 67.5 million tonnes in 2002 (Figure 8). This is better than the Canadian average (which rose an average of 2.8% annually). However, compared to other provinces, much of British Columbia's population lives in a relatively mild climate that does not require as much energy for winter heating. Another advantage is that the province obtains much of its electricity from hydroelectric generation rather than fossil fuel burning. Greenhouse gas emissions per capita in BC were 16.4 tonnes of CO_2 equivalent in 2002. This continues an upward trend that started in 1997, when emissions were 15.4 tonnes per person (e.g., BCMWLAP 2002a); however, British Columbia remains the province with the third lowest per capita emissions in Canada.

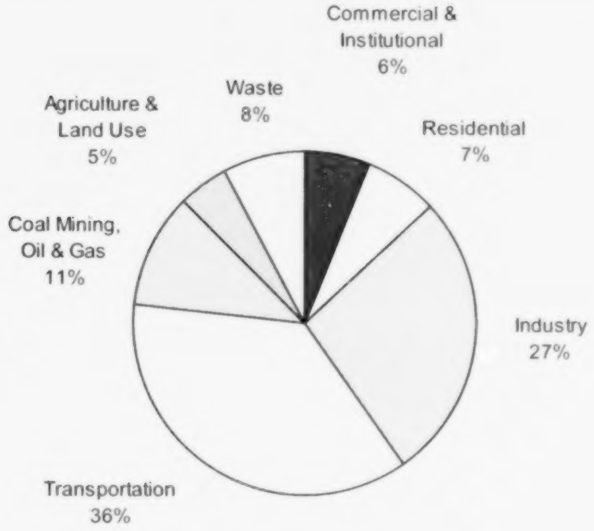
Figure 8. Total greenhouse gas emissions in British Columbia 1990 to 2002 in megatonnes of CO_2 equivalents.



Source: Environment Canada 2003, *www.ec.gc.ca/pdb/ghg/1990_02_report/ann10_e.cfm.*

More than 90% of the greenhouse gas emissions in Canada are associated with the consumption and production of energy. Figure 9 shows the sources of greenhouse gas emissions in the province. The largest source is the transportation sector, which includes commercial and private vehicles of all kinds. Of particular concern for coastal British Columbia is a recent report forecasting significant net increases in emissions from marine vessels in the Lower Fraser Valley region. This source is expected to increase the CO_2 equivalent emissions for that region by 52% over the next 20 years (GVRD 2003).

Figure 9. Sources of greenhouse gas emissions in British Columbia (2002).



Source: Environment Canada 2004.

WHY IS CLIMATE CHANGE IMPORTANT?

For British Columbia, the type of climate-related changes predicted for the 21st century include:

- a reduced snow pack in southern BC and at mid elevations;
- an earlier spring freshet on many snow-dominated river systems;
- reduced summer stream flows, particularly on snow-dominated river systems;
- glacial retreat and disappearance in southern BC;
- warmer temperatures in some lakes and rivers;
- reduced summer soil moisture in some regions;
- increased frequency and severity of natural disturbances such as fire, diseases, pest outbreaks;
- large-scale shifts in ecosystems and loss of ecosystems, including some wetland and alpine areas;
- an increase in growing-degree days.

Such changes will affect communities and the provincial economy. The type of socio-economic impacts that may occur were seen in 2003 when some parts of the coast and the Southern Interior experienced the most serious drought conditions in more than a hundred years. Utilities rationed water, cattle were culled, and salmon died from heat stress in waters that were too warm. Dry forest conditions contributed to some of the worst forest fires in provincial history. The total cost of the 2003 fires is estimated at $700 million (Filmon 2004). Although the extreme events of 2003 may be a weather anomaly, they are also consistent with global projections of an increased probability of extreme weather (Stott et al. 2004).

Another example of the link between climate change and large socio-economic impact is the spread of mountain pine beetle in British Columbia, which threatens most of the merchantable pine in the province and will cause major changes in local economies (see text box).

CLIMATE CHANGE OPPORTUNIST: MOUNTAIN PINE BEETLE

Warmer winters and longer growing seasons of recent years are associated with the current mountain pine beetle outbreak in British Columbia. The larvae of the beetles overwinter in pine trees. In the early stage, the larvae are vulnerable to cold winter temperatures, but late-stage larvae can withstand temperatures close to –40°C. With a longer growing season, more larvae reach the cold-hardy stage before winter sets in, and with fewer cold winters, more survive through to the following year. It is anticipated that as the climate warms, the beetle will significantly expand its range in British Columbia (Carroll et al. 2002). Forestry researchers now believe that the beetle population is so large and widespread that it is predicted to kill more than 80% of mature pine trees in the province by 2020 (Eng et al. 2004).

WHAT IS BEING DONE ABOUT CLIMATE CHANGE?

Reducing greenhouse gas emissions on a global scale is expected to slow the rate—and possibly the magnitude—of climate change. However, IPCC scientists estimate that greenhouse gas emissions must be reduced by 50–60% just to stabilize global atmospheric concentrations of carbon dioxide at 500 ± 50 ppm (nearly double the pre-industrial concentration) by the middle of the next century (Pacala and Sokolow 2004).

The 1992 United Nations Framework Convention on Climate Change—supported by most nations including Canada and the United States—stated that global atmospheric concentrations of these gases must be stabilized at a level that would prevent dangerous interference with the climate system. The largest international agreement on climate change is the Kyoto Protocol, which came into force internationally in February 2005.

after being ratified by 140 nations. It calls on the 35 most industrialized nations to reduce fossil fuel emissions of carbon dioxide and other greenhouse gases to an average 5.2% below 1990 levels. Canada ratified the Kyoto Protocol in 2002, committing to reduce total greenhouse gas emissions across the country to a level 6% below that of 1990. It commits Canada to reaching this target by 2012.

Improvements in energy efficiency in Canada reduced the growth in energy consumption by 13% from 1990 to 2002 (Behidj et al. 2004). Despite increased efficiencies, however, energy use continues to grow as the Canadian population and economy expand. For example, greenhouse gas emissions from the residential sector in Canada were 8% higher in 2002 than in 1990 (Behidj et al. 2004). Global emissions of most greenhouse gases have increased since 1992 (Houghten et al. 2001).

Even if countries succeed in reducing future greenhouse gas emissions, the excess greenhouse gases already in the atmosphere are expected to continue to drive climate change and its impacts for centuries. An effective response to climate change therefore also includes long-term planning to adapt to the impacts.

In 2005, the federal government released the report "Moving Forward on Climate Change: A Plan for Honouring our Kyoto Commitment" (see *www.climatechange.gc.ca*). With the change in government, the plan is currently under review.

In December 2004, the province released "Weather, Climate and the Future: BC's Plan." The plan outlines how the province will work with the federal government, industry, local government, and individuals to address climate change. It lists 40 actions aimed at reducing greenhouse gas emissions and adapting to climate change. The Plan establishes a provincial target to maintain or improve on BC's ranking as the third lowest emitter of greenhouse gases per capita among the provinces. In addition to this aggregate target, specific targets will be set for agriculture, buildings, government operations, and other sectors (see *www.env.gov.bc.ca/air/climate/index.html*).

Five main areas of the Plan emphasize:

- cost effective actions that both address greenhouse gas emissions and enhance competitiveness;
- efficient infrastructure and opportunities for innovation;
- management of forest and agricultural land to enhance carbon sinks and reduce impacts in BC forests;
- reduction of emissions from government operations, increased public outreach, and establishment of partnerships with other jurisdictions;
- research to improve understanding of impacts on water resources and to increase capacity to adapt to droughts and floods.

The industry and business sectors in the province are responding to the challenge of reducing greenhouse gas emissions. Here are just a few of many examples:

- Duke Energy has completed three acid gas reinjection projects at facilities in northeastern British Columbia that reduce their annual greenhouse gas emissions to the atmosphere by approximately 140 kilotonnes.
- Lafarge North America rebuilt its Richmond cement plant with new technology in 1999, reducing their greenhouse gas emissions from burning fuels by more than 25%.
- Telus's Vancouver head office saved an annual 520 tonnes of greenhouse gas emissions through a state-of-the-art renovation. By reusing steel and concrete during the renovation, Telus also avoided 15,300 tonnes of greenhouse gas emissions that would have been emitted had new materials been used.
- Green Buildings BC, a BC Buildings Corporation initiative, has supported and monitored four pilot building programs whose energy savings are 26–41% better than the Model National Energy Code for Buildings standard.
- VanCity Credit Union offers energy efficiency loans tailored to businesses, and is the first financial institution in Canada to introduce a low-interest Clean Air Car Loan for hybrid vehicles.

WHAT CAN YOU DO?

Individual Canadians are responsible for about one-quarter of all greenhouse gas emissions, mainly from energy used for driving and in the home.

A very important step consumers can take is to consider fuel economy when purchasing a vehicle. Road transportation is responsible for almost a quarter of all greenhouse gas emissions, amounting to 15.6 million tonnes in 2003 for British Columbia. Personal transport, made up of cars and light trucks together, accounts for about two-thirds of this figure and is the largest single emissions category in the province and across the country.

Despite advances in technology, the fuel economy of the average Canadian's personal vehicle has actually been getting worse since 1986, largely due to the popularity of light trucks, a class of vehicles that includes sport utility vehicles (SUVs) (Schingh et al. 2000). Although new vehicles are cleaner and more efficient than those produced 20 years ago, trends show increasing numbers of heavier and more powerful vehicles, travelling greater distances, which leads to higher total fuel consumption and increasing emissions of CO_2.

DID YOU KNOW THAT:

- When driven for 25,000 km, an average car saves about 2 tonnes of greenhouse gas emissions compared to an average light truck or SUV. It costs 42% more for fuel to drive the same distance in an average light truck than in an average car. There is an even greater saving in driving a small, fuel-efficient car.
- Idling for 10 minutes a day can produce about a quarter tonne of CO_2 emissions each year.
- About 70% of cars and light trucks have at least one tire that is over- or under-inflated. Maintaining the correct tire pressure could reduce vehicle greenhouse gases by at least one-eighth of a tonne each year.
- A compact fluorescent light bulb lasts up to ten times longer and uses a quarter of the electricity of a regular incandescent light bulb. Replacing all the bulbs in a home with compact fluorescent bulbs could reduce greenhouse gas emission by another eighth of a tonne annually.

Source: Canada's Guide to the One-Tonne Challenge, 2005.

Residential energy use is the second major area for reducing personal contributions to greenhouse gases. Households use energy mainly for space heating and cooling, hot water, lighting, and operating appliances. Even considering hydroelectric production of electricity in British Columbia, residential use is still a relatively large source of greenhouse gas emissions in the province (about 7.5% of the total).

Ways households can save energy and help reduce greenhouse gas emissions include:

- Obtain an energy audit for the home and follow recommendations to reduce consumption.
- Use automatic setback thermostats for night-time and periods of absence.
- Select lighting fixtures and bulbs that use less energy.
- Turn off lights and computer equipment at night.
- Select appliances with an Energy Star rating when purchasing new ones.

Much more information for individuals, communities, local government, and industry is available at these sources:

- The Greenhouse Gas Action Guide (*www.ghgactionguide.ca/*) describes initiatives in agriculture, transportation, and waste generation to help industry, business, and individuals reduce greenhouse gas emissions.
- The BC Climate Exchange (*www.bcclimateexchange.ca*) provides a clearinghouse for educational resources, ways to reduce emissions, and lists of events and funding opportunities.

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Industrial Contaminants

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Industrial Contaminants

BACKGROUND

Thousands of chemicals and other substances are in use in Canada. Some are intended for controlled use in the environment (such as pesticides and water purification chemicals), some may be released into the environment as byproducts (such as from burning wood and petroleum products) or accidentally through spills and leaks. Apart from pesticides and pharmaceuticals, which are regulated under other acts, 52 substances are currently defined as toxic under the Canadian Environmental Protection Act. CEPA defines a substance as toxic if it enters, or may enter, the environment in amounts or under conditions that may pose a risk to human health or the environment. Substances are also considered to be toxic if any products formed as they break down in the environment meet this definition.

Many possible environmental contaminants could be discussed in a review of toxic substances from industrial sources. The emphasis in this paper is on persistent pollutants, largely from land-based activities, that have been released into the coastal and marine environment; mercury and polycyclic aromatic hydrocarbons (PAHs) are important contaminants also included in this review.

The indicators in this paper were chosen to represent a spectrum of issues and consequences. Indicators show what is, or was, discharged into the marine environment, the movement of persistent pollutants through food webs and ecosystems, and the effect of regulatory efforts to control pollutants.

CONTAMINANT DEFINITIONS

In this paper, the term "contaminant" refers to substances, including those found naturally, that are present at concentrations above natural background levels, or whose distribution in the environment has been altered by human activity.

The term "pollutant" refers to a contaminant whose concentration in the environment is high enough to result in deleterious effects (GESAMP 1983).

Persistent Organic Pollutants (POPs)

Most of the indicators in this paper concern the group of substances known as persistent organic pollutants (POPs). They persist for a very long time in the environment because they resist being broken down by chemical and microbial processes. These chemicals have a variety of toxic effects, including disruption of hormone and immune systems of mammals. POPs include a wide variety of chlorinated and other halogenated chemicals, such as dioxins and furans, polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and other less well understood chemicals. They are fat soluble and accumulate in the fat reserves of organisms because they are resistant to being broken down metabolically. Through the process of bioaccumulation, such compounds become more concentrated as living organisms take them up and store them in body tissues faster than they can be broken down or excreted. When contaminated organisms are eaten by other animals, the compounds become more and more concentrated in the bodies of the predators. In a process called biomagnification, concentrations tend to increase at each step up the food web, often reaching high levels in the top predators. The concentration of PCBs in harbour seals, for example, may be five times higher than in the fish they consume (Cullon et al. 2005) and thousands of times higher than the PCB concentration in the surrounding seawater (Macdonald et al. 2003). This means that POPs may accumulate in wildlife to concentrations that affect their health or risk the health of humans who consume them.

POPs were mostly used in industrial applications or are byproducts of incineration or other industrial processes; some were used as insecticides. As a group, POPs vary greatly in their toxicity, persistence in the environment, and how they are transported once they enter the environment. Many are now banned or are subject to stringent regulations controlling their use and release. After restrictions on their production and use came into effect from the 1970s onward, concentrations of several POPs in the Canadian environment decreased substantially. Because they resist chemical decomposition, however, the contaminants already in the environment continue to circulate.

The main groups of POPs discussed in this paper are PCBs, dioxins and furans, PBDEs, PAHs, mercury, and DDT.

PCBs

Polychlorinated biphenyls (PCBs) are a class of stable, waxy to oily compounds that were used as heat-resistant coolants or insulators in electrical equipment. They were also used as plasticizers, solvents, and degreasers, and in several industrial processes. There are 209 different forms or congeners of PCBs. Congeners are variants on a common chemical structure; although related, they differ in toxicity and their fate in the environment. The PCBs sold and used commercially were mixtures of congeners.

Restrictions on industrial uses of PCBs began around 1971. Manufacture, import, and most non-electrical uses of PCBs were banned in North America in 1977 and it was made illegal to release PCBs to the environment in 1985. Canadian legislation allows PCBfilled equipment to be used until the end of its service life, but handling, storage, and disposal are subject to stringent government requirements. As a result of these measures, the quantity of PCBs in use declined by 54% between 1992 and 2003 (Environment Canada 2005a). Most PCBs now enter the environment through leaks or improper disposal of waste oils and electrical equipment.

PCBs have a wide range of toxic effects. They adversely affect the immune, reproductive, neurological, and endocrine systems of mammals, including causing cancer (Safe 1993). The toxicity and properties of the congeners largely depend on the number and positions of chlorine atoms in the molecule. The most toxic PCB congener, PCB-126, presents about one-tenth the risk to humans of the most toxic dioxins (discussed below). With respect to toxicity, PCBs can be generally considered in two groups: One group of about a dozen congeners are structurally similar to the highly toxic dioxin 2378-TCDD and have similar, dioxin-like effects on immune systems and fetal development. The toxic effects of other PCB congeners stems from their metabolic breakdown into highly toxic intermediate compounds that affect thyroid and vitamin A physiology.

Dioxins and Furans

The dioxins (polychlorinated dibenzo-p-dioxins) consist of a group of 75 congeners; furans (polychlorinated dibenzo-p-furans) are a group of 135 congeners. The most toxic dioxin congener is 2,3,7,8-TCDD. It is the standard for comparing the relative toxicity of other compounds with dioxin- and furan-like activity (see text box: Toxic Equivalents).

These compounds form as byproducts of industrial activities such as chlorine bleaching in pulp mills and incineration of municipal and industrial wastes. Dioxins and furans are structurally similar to PCBs and were also unintended contaminants of commercial PCB formulations and some herbicides. The 2,3,7,8-TCDF congener first appeared in sediments in the early 1960s when pulp mills converted to chlorine liquid bleaching. Although trace amounts continue to be produced by industrial incineration, environmental concentrations of dioxins and furans have decreased with the phase-out of PCBs and changes in pulp and paper mill technology. Because dioxins and furans have a strong affinity for sediments, however, they will remain in the marine environment for decades and will eventually be buried by accumulating sediments.

Long-term exposure in mammals to 2,3,7,8-TCDD can affect reproduction, cause cancer and birth defects, damage the liver, and suppress the immune system (Environment Canada 1990). Rainbow trout exposed to this congener died at concentrations as low as 40 parts per quadrillion (Mehrle et al. 1988). People exposed to dioxins and furans may develop chloracne (a skin condition caused by acute exposure), liver and immune system dysfunction, and show other sensory and behavioural effects, and the US Environmental Protection Agency has classified 2,3,7,8-TCDD as a probable human carcinogen (ATSDR 1998). Because there is the potential for fish and shellfish to bioaccumulate dioxins and furans, people who eat large amounts of seafood may be at risk (reviewed in Ross and Birnbaum 2003).

TEFs & TEQs: TOXIC EQUIVALENTS

A system has been devised to estimate the combined toxic effect of the most common congeners of dioxins, furans, and PCBs. It is based on the similarity between species in the physiological effects of toxicity. Each congener is assigned a toxic equivalency factor (TEF) relative to the most toxic dioxin (2,3,7,8-TCDD), which has been assigned a TEF of 1 (see the table, below). For example, the TEF of PCB#126 for mammals and birds is 0.1, because research has determined that PCB#126 is one-tenth as toxic as 2,3,7,8-TCDD to these organisms. There are some differences in sensitivity between species: for example, fish are less sensitive to PCB#126 than mammals or birds, and are therefore assigned a lower TEF value (0.005). The toxicity of a congener is calculated by multiplying its TEF by the concentration found in the environment to arrive at the toxic equivalent concentration or TEQ. The total toxicity of a PCB, dioxin, or furan mixture is estimated by summing the TEQs of the congeners.

Examples of Toxic Equivalency Factors (TEFs) for mammals, birds, and fish.

	Congeners	Mammals	Birds	Fish
Dioxins	2,3,7,8-TCDD	1	1	1
	1,2,3,7,8-PCDD	1	1	1
	1,2,3,4,7,8-HCDD	0.1	0.05	0.5
	OctaCDD	0.0001	0.0001	<0.0001
Furans	2,3,7,8-TCDF	0.1	1	0.05
	1,2,3,7,8-PCDF	0.05	0.1	0.05
	2,3,4,7,8-PCDF	0.5	1	0.5
	1,2,3,4,7,8-HCDF	0.1	0.1	0.1
	OctaCDF	0.0001	0.0001	<0.0001
Non-ortho PCBs	PCB#77	0.0001	0.05	0.0001
	PCB#126	0.1	0.1	0.005
Mono-ortho PCBs	PCB#105	0.0001	0.0001	<0.000005
	PCB#123	0.0001	0.00001	<0.000005

Source: Van den Berg et al. 1998.

PBDEs

Polybrominated diphenyl ethers (PBDEs) are widely used today as flame retardant chemicals in consumer products. One form used in polyurethane foam has been phased out, but others are added to plastics used in furniture upholstery, carpet backings, electrical insulation, computer and TV cases, and other consumer goods. Mammalian toxicity of the 209 congeners of PBDEs is thought to increase as the number of bromine atoms in the molecule decreases (Gill et al. 2004), but further research is needed to understand the mechanisms of PBDE toxicity. The smaller molecules also bioaccumulate more readily and account for most of the environmental residues (Rayne and Ikonomou 2002). PBDEs are less toxic than PCBs but are structurally similar and have similar environmental properties. They are generally soluble in fat and biomagnify within the food chain, but they are more susceptible to environmental degradation than PCBs.

PBDEs can be released into the environment during production, but the main environmental source is escape from consumer products during use and after disposal. They are broken down in surface water and sediment through microbial degradation and other metabolic processes (e.g., Gouin and Harner 2003). Laboratory studies have shown that as PBDEs with more bromine atoms break down in the environment they lose bromine atoms, thus may be transformed into more toxic, mobile, and bioaccumulative forms.

Production of PBDEs ramped up during the 1970s. Three commercial mixtures of PBDEs have been manufactured: deca-dibromodiphenyl ether (decaBDE, which accounted for about 80% of the North American market before 2004), octa-dibromodiphenyl ether (octaBDE), and penta-dibromodiphenyl ether (pentaBDE). Production of the octa- and penta- mixtures was banned by the European Union (EU) and voluntarily discontinued by the only North American manufacturer in 2004. DecaBDEs are not currently regulated and continue to be used around the world. According to the revised EU risk assessment, global production of decaBDE was 56,100 tonnes in 2001. The majority (ca. 80%) is used in the plastics and electronics industry in the manufacture of circuit boards, wire coatings, and mobile telephone equipment. The remaining 20% of world use is for textiles, upholstery, cables, and insulation materials.

PBDEs enter the human body by ingestion or inhalation. They are suspected of causing cancer, decreasing thyroid hormone levels, and disrupting endocrine systems (McDonald 2002), causing liver toxicity, immune system effects (Gill et al. 2004), hyperactivity, and reproductive effects (Kuriyama et al. 2005).

Matching the increasing production and use of PBDEs, concentrations in animal tissue and human milk have increased steeply during the last decade (Rahman et al. 2001; Hites 2004). In Canada, PBDEs have been found in human breast milk and blood, food, indoor and outdoor air, and water (Health Canada 2004a,b,c,d). A recent Health Canada study showed that Canadian women have the second highest concentrations of PBDEs in their breast milk in the world after women in the USA (Ryan 2004). PBDEs in the breast milk of Vancouver women increased almost 10-fold between 1992 and 2002, from 3 ng/g to 20 ng/g (Ryan et al. 2002). PBDE concentrations in indoor air and household dust in

Canadian (Wilford et al. 2004) and US (Stapleton et al. 2004) homes were found to be high enough to create a potential health risk to young children, whose hand-to-mouth activity exposes them to greater amounts of household dust than adults. The effect of these residues, if any, is largely unknown, but no studies have conclusively linked present PBDE concentrations in humans to health effects (Health Canada 2004a). The threshold for toxicity in animal studies is 100 to 1000 times greater than exposure estimates for the currently most-exposed humans (LaFlamme 2005).

POPs IN FISH: TO EAT OR NOT TO EAT?

Recent studies have found detectable levels of PCBs, dioxins, and some persistent pesticides in wild and farmed BC salmon (e.g., Hites et al. 2004).

In 2002, Health Canada found low levels of PCBs in fish and seafood purchased in Vancouver, with average values not exceeding 17 ng/g (Health Canada 2004c). Farmed Atlantic salmon contained the highest average level (16.8 ng/g), approximately 2.5 times the level in the wild salmon samples.

In 2003, Health Canada found PBDE concentrations in retail samples of seafood up to 5.5 ng/g (parts per billion, ppb). Farmed salmon contained an average concentration of 2.2 ng/g (Health Canada 2004c) and wild BC chinook averaged 2.9 ng/g PBDEs. Health Canada has considered the risk to human health from reported levels of PBDEs in fish and seafood, available toxicological information, and estimated dietary fish and seafood consumption. They concluded that levels found in seafood to date are not a health concern for average Canadian consumers (Health Canada 2004c), and advised consumers that the known health benefits of eating fish and other seafood outweigh the risks from present contaminant levels.

PAHs

Polycyclic aromatic hydrocarbons (PAHs) are generally thought to be the most widespread of the organic contaminants (e.g., Garrett, 2004). They may bioaccumulate to some extent, depending on the ability of different organisms to metabolize them, but do not tend to biomagnify up the food chain. Spilled oil may be the best-known source of PAH contamination, but the highest concentrations at contaminated sites have come from petroleum refining processes and coal tar production. PAHs are found in industrial liquid effluents, including those from pulp mills and aluminium smelters, and are often found in harbours.

Atmospheric deposition is thought to be the major source of PAHs in most aquatic systems (Garrett 2004). Atmospheric sources include fossil fuel combustion, slash burning, and forest fires. Other sources include contamination from liquid petroleum products and creosote, as well as from urban activities (roads, wastewater treatment plants, urban runoff; Yunker et al. 2000). There are also natural sources, such as oil seeps, coal, plant debris, and forest fires.

PAHs can be separated into the "parent" group of compounds, such as naphthalene, and the structurally similar alkylated PAHs, such as 3-methylnaphthalene. Most alkyl PAHs appear to be at least as toxic as the parent compounds. They also persist for a longer time than their parent compounds, are less water soluble, and tend to bioaccumulate to a greater degree (Irwin et al. 1997). As petroleum products age, the percentage of alkyl PAHs increases compared to parent PAHs. Because there are natural sources for both, the levels of parent and alkyl PAHs found in the environment as a result of human activity must be evaluated against the natural background (Yunker et al. 2002).

Hazards from PAHs in the aquatic environment are often difficult to assess due to the great number of parent PAHs and alkyl PAHs of potential concern and the number of variables that can either increase or decrease the risk. In general, PAHs bioaccumulate but do not biomagnify. Concern has focused on the metabolic breakdown of benzo[a]pyrene and several other PAHs into metabolites that are far more carcinogenic and hazardous than the parent compounds (e.g., Irwin et al. 1997). Total PAHs as low as 1 mg/kg have been shown to induce tumours in brown bullhead catfish (Eisler 1987), but the significance of this finding is not known.

Mercury

Unlike other metals, mercury bioaccumulates and biomagnifies in aquatic food webs and can present a health risk to high-level consumers. Mercury occurs as elemental mercury, inorganic salts, and in organic forms. It occurs naturally in soil and rocks and is a byproduct of industrial processes, incineration, and metal smelting. Mercurial compounds are also used in scientific research and pharmaceuticals. Elemental mercury is relatively inert, but other forms are very toxic. Organic mercury compounds, such as methyl mercury, are used medically as fungicides and antibacterials, but the main source of human poisoning is through eating mercury-contaminated fish. Mercury is released from flooded soils and vegetation in reservoirs, where bacteria use the organic carbon in soils to produce methyl mercury from natural concentrations of inorganic mercury (e.g., Brigham et al. 2002). Methyl mercury biomagnifies in aquatic food webs, in invertebrates, fish, birds, and mammals (e.g., Bodaly and Fudge 1999). The highest concentrations occur in large, longer-lived animals and in species at the top of the food chain.

Mercury's primary health effects are neurological, but high exposure can also permanently damage the brain and kidneys and cause birth defects in humans (e.g., reviewed in Clarkson 1997) and wildlife (e.g., Wolfe et al. 1998). Children are particularly susceptible to its toxic effects. Methyl mercury easily passes the placental barrier, where it can damage the brain and neurological system of the fetus.

Like other heavy metals, mercury enters the marine environment from many sources, including coal-fired power stations, industrial processes, wastewater outfalls, mine effluents and discharges, atmospheric emissions, as well as natural ore deposits. Mercury contamination is of international concern, with many countries, including Canada, taking stringent measures to regulate and reduce emissions. Mercury emissions from metal smelting in Canada have been significantly reduced since 1988, as have releases from chloralkali manufacturing, pesticides, paints, and batteries. Heavily contaminated tailings are still present, however, in historic gold mining areas, where it was used in the 19th and early 20th centuries (Pacyna and Pacyna 2002). Mercury from metal smelting, coal-fired utilities and municipal waste incinerators is transported globally in the atmosphere. Best estimates suggest that human activities have about doubled or tripled the amount of mercury in the atmosphere, with the atmospheric burden increasing by about 1.5% per year (Johannessen et al. 2005a).

DDT

The once commonly used pesticide DDT (dichlorodiphenyl trichloroethane) breaks down in the environment into DDE (dichlorodiphenyl dichloroethylene)—a highly persistent and endocrine disrupting chemical. DDE is produced in most animals when the body attempts to break down and excrete DDT; it was also a contaminant in DDT formulations. DDT was used in Canada to control biting insects and agricultural and forest pests from 1947 to 1969. DDT was banned after it was discovered that metabolites of DDT (mainly DDE), bioaccumulating in tissue of predatory birds, disrupted the layering of calcium in their eggs, causing egg-shell thinning and breakage. In Canada, DDT was banned in 1972 and its use is also currently prohibited in the US and Europe. It continues to be used elsewhere in the world to control mosquitoes that carry malaria and on agricultural crops.

DDE residues from past DDT use are still measurable in soil, sediment, and wildlife. These residues continue to be augmented by atmospheric transport of DDE from other continents where DDT is still in use.

ENDOCRINE DISRUPTING SUBSTANCES

Most of the POPs discussed in this report have endocrine disrupting properties in addition to other toxic effects. Endocrine disrupting substances (EDS) mimic or block vertebrate steroid hormones by interacting with hormone receptors in the body's hormone regulatory system. Typical effects include feminization of male animals or masculinization of females (e.g., Matthiessen et al. 2000 study of fish in estuaries), eggshell thinning in birds, and disruption of vitamin A and thyroid hormone physiology in mammals. Although such effects were not suspected until research in the late 1980s began to raise questions, it is now a key area of research because of the health implications.

A major British research project on endocrine disruption in the marine environment (EDMAR) found feminization of flounder and of blenny (a small forage fish) in some estuaries (DEFRA 2003). Although the impacts of EDS have not been as well studied in BC, elevated levels of egg proteins have been found in male rockfish (West et al. 2001) and English sole (Lomax et al. 2001) from sites in Puget Sound.

The range of EDS effects on animal behaviour may be more widespread than originally thought. Recent studies on a wide range of organisms, including fish, mice, birds, and primates, found changes in social and mating behaviour, increases in hyperactivity and aggression, impaired motor skills, and reduced ability to learn (Clotfelter et al. 2004; Zala and Penn 2004).

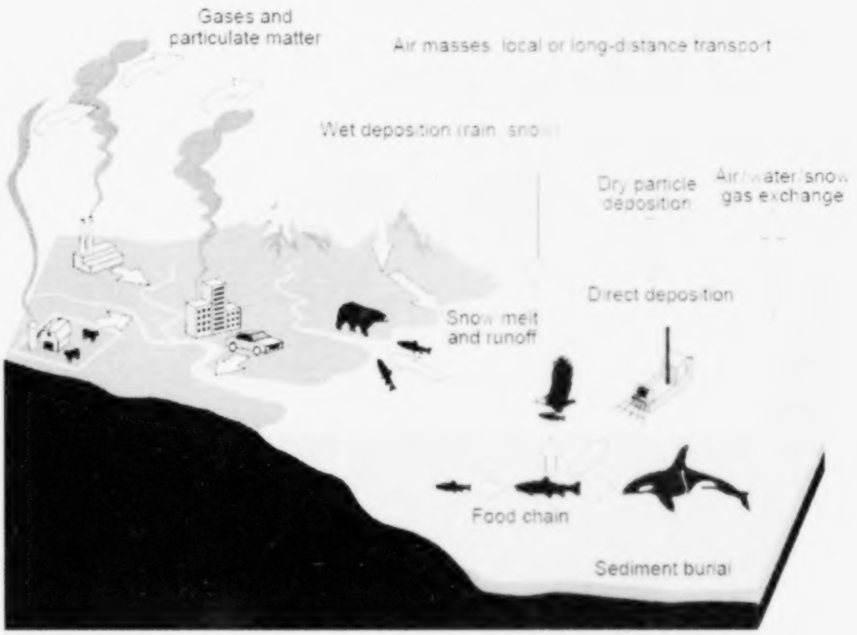
How Contaminants Move in the Environment

Contaminants enter the coastal environment directly and indirectly through several routes (Figure 1). They may originate from a specific outlet ("point source"), such as a discharge pipe from an industrial factory; they also may come from "non-point sources," which are the many and diffuse sources of pollutants, such as those carried off the land in urban or agriculture runoff. From such sources, they may be discharged directly into water near the shoreline or into rivers that carry the contaminants to the marine environment. POPs do not dissolve easily in water, but they can become weakly attached (adsorbed) to suspended particles in the water, which eventually carry them to the bottom. From there, contaminated sediments may be gradually covered over by new material brought down by rivers or carried along in coastal currents.

Contaminants are also emitted into the air from combustion, incineration, and industrial processes. They may also enter the atmosphere as vapours re-emitted from chemical residues already in the environment. Once in the atmosphere, POPs can travel great distances before being deposited. They may be directly deposited on land or water by precipitation or on dust particles. The vapour form of contaminants may also enter water or snow through gas exchange processes. Once in the atmosphere, POPs travel on prevailing winds until the air masses reach cool regions, such as mountaintops and high latitudes, where the vapours condense. The chemicals may accumulate in ice or snow until they are released into ecosystems through snow melt and spring runoff (e.g., Li and Macdonald 2005). Many small lakes and reservoirs in the Rocky Mountains fed by glacial runoff contain concentrations high enough to affect wildlife at the top of the food chain (e.g., Hempel 2000).

Contaminants enter the marine food chain when they are taken up by organisms living in the water column or sediments. The contaminants attach to the lipids in the cells of organisms and bioaccumulate within organisms. Through the process of biomagnification as larger organisms eat smaller ones, the contaminants move through the food chain, becoming concentrated in top predators.

Figure 1. Direct and indirect routes for movement of POPs in the environment.


Gases and particulate matter
Air masses: local or long-distance transport
Wet deposition (rain, snow)
Dry particle deposition
Air/water/snow gas exchange
Direct deposition
Snow melt and runoff
Food chain
Sediment burial

Source: Based on Ross and Birnbaum (2003), with additional sources.

TBT: HISTORY OF A MARINE CHEMICAL

Tributyltin (TBT) was widely used as the active ingredient in antifouling paints to prevent the growth of marine organisms on ships' hulls and underwater structures. It is toxic to many aquatic organisms, including fish, molluscs (especially whelks, oysters, and clams), and other benthic animals. It slows growth, causes abnormal shell development, kills larvae, and is also an endocrine disrupting substance. At extremely low concentrations (4–10 ng/L), it causes imposex (the imposition of male characteristics on females) in marine snails (EPA 2002). In some areas of BC (e.g., Burrard Inlet), TBT contamination had eradicated whelk populations by 1989, and juvenile whelks failed to mature in other areas (Bright and Ellis 1990).

Canada restricted most uses of TBT-based antifouling paints in 1989 and later banned all uses of TBT in November 2002 (PMRA 2002). In December 2004, the last US producer of TBT-based paint requested voluntary cancellation of its product registration. An international resolution has been put forward to phase out TBT-based paints with a full prohibition to be in place by 2008 (IMO 2001).

Despite Canadian prohibitions, significant concentrations of TBT are likely to remain in sediment for 20 to 30 years (Stewart and Thompson 1997; Maguire 2000). At the Ogden Point breakwater in Victoria, all female whelks sampled in 2000 showed reproductive effects caused by TBT, which was 11 years after most uses were banned (Reitsema et al. 2002). Because the ban is not yet worldwide, there will also continue to be some new TBT inputs as ships with TBT-based hull paint enter BC waters.

INDICATORS

1. Key Indicator: Trends in dioxin and furan levels in pulp and paper mill effluent, sediments, and Dungeness crab tissues

This is both a pressure and a response indicator. It shows the past pressure on the environment from dioxins and furans in pulp mill effluents and the results of the societal response by governments and industry to eliminate this pressure on the environment. The indicator addresses the questions: What is the impact of industrial pollutants released to the environment? Are efforts to protect the environment from industrial pollutants effective?

In BC, elevated dioxin and furan concentrations were first found in edible fish and shellfish collected near coastal pulp and paper mills between 1987 and 1989. After investigation showed that the chemicals were being generated as a byproduct of the pulp bleaching process, both the federal and provincial government introduced regulations to control dioxin and furan discharges. The initial impetus for industrial change came from BC provincial regulations in 1990, which established a legally binding requirement to eliminate adsorbable organic halide (AOX)—a surrogate measure of the amount of chlorinated organic compounds in pulp and paper effluent. Federal regulations in 1992 prohibited release of dioxins and furans above certain levels, required pulp mills to conduct annual monitoring, and closed crab and shellfish fisheries in affected areas. This indicator shows the effect of regulatory measures and changes in mill technology as industry complied.

Methodology and Data

Data for this indicator were collected under two federal programs:

- The Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations (1992), of the Canadian Environmental Protection Act. The regulations prohibited the release of 2,3,7,8-TCDD in pulp and paper mill effluents above 15 parts per quadrillion (ppq) and of 2,3,7,8-TCDF above 50 ppq by 1 January 1994.
- The Coastal Mills Dioxin and Furan Trend Monitoring Program. This federal program requires mills on the BC coast to monitor dioxins and furans in the environment around their effluent outfalls. Environment Canada specifies the sampling locations, species, and numbers of samples to be collected annually. Data are reviewed by Health Canada, which conducts a human health risk assessment for consumption of Dungeness crab. Fisheries and Oceans Canada reviews the data and health risk assessment to evaluate the need for fisheries closures and advisories.

Sampling Methods

Mill effluent: Under the Pulp and Paper Mills Chlorinated Dioxins and Furans Regulations, mill operators are required to collect 24-hour composite samples of their final effluent and determine the concentrations of all toxic congeners of dioxins and furans. Data for this indicator came from samples collected at least once a year, more frequently if the mill found a measurable concentration of dioxins or furans. Samples were analyzed with high-resolution gas chromatography/high-resolution mass spectrometry for 27 different dioxin and furan congeners (Environment Canada 1992).

In 1991, nine pulp and paper mills discharged secondary-treated effluent to BC's coastal waters and were included in the monitoring program. Since then, some mills have closed and others have switched to bleaching technology that does not use elemental chlorine. By 2002, six mills and by 2004 only three mills required annual monitoring.

Sediment: Three sediment samples were taken annually at the same location close to each mill outfall. A composite of the top 2 cm of the three samples was analyzed similarly to the mill effluent. TEQs were derived using internationally accepted procedures (see text box: Toxic Equivalents).

Crab tissue: Adult Dungeness crabs (*Cancer magister*) concentrate POPs in their fat-rich digestive gland (hepatopancreas). This was chosen as an indicator species because the crabs do not move large distances and can therefore be used to indicate local levels of contamination. They have a relatively long life span and are widely distributed, preferring sandy-bottomed waters where contaminated sediments often accumulate. The crabs are also economically important because they are fished commercially and recreationally.

Dungeness crabs collected for analysis were legal-sized males (minimum carapace width, 165 mm). They were collected from sites near mill outfalls, usually in March. The hepatopancreas samples of up to seven crabs collected near each mill outfall were combined into a single sample. Dioxin and furan analyses were conducted using ultra-trace high-resolution gas chromatography/high-resolution mass spectrometry. TEQs were derived using the internationally accepted procedure (Van den Berg et al. 1998).

Results from all three types of sampling are reported in Tables 1 to 3 and displayed graphically in Figure 2.

Table 1. Effluent loadings of the dioxin 2,3,7,8-TCDD from coastal BC pulp and paper mills, 1989 to 2003 (mg per day).

Mill	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Crofton	6.32	0.99	2.60	0.28	0.31	0.40	0.31	0.28	0.20	0.15	0.16	ND	ND	ND	–
Elk Falls	5.82	6.22	1.16	0.65	1.13	0.57	0.33	0.39	0.29	0.21	0.20	ND	ND	ND	ND
Gold River	–	–	1.50	0.12	0.55	0.50	0.77	0.50	0.27	Closed					
Harmac	6.22	–	0.84	2.61	0.40	0.32	0.32	0.33	0.60	0.56	0.14	ND	ND	ND	–
Port Alberni	–	–	0.65	0.37	0.58	No chlorine in use									
Port Mellon	19.29	1.91	0.31	0.16	0.13	0.12	0.16	0.16	0.11	0.14	0.08	ND	ND	ND	ND
Powell River	–	4.51	3.57	0.33	0.55	0.80	0.21	0.30	0.38	0.37	0.26	ND	ND	Kraft mill closed	
Skeena	9.77	2.79	3.31	7.44	0.76	0.53	0.41	0.37	0.18	0.30	0.07	ND	Not operating		
Squamish	3.46	1.60	0.70	0.46	0.50	0.17	0.20	0.15	0.14	0.10	0.10	ND	ND	ND	ND
No. of mills reporting	6	6	9	9	9	8	8	8	8	7	7	7	6	5	5
Total	50.88	18.02	14.64	12.42	4.91	3.41	2.71	2.48	2.17	1.83	1.01*	1.00*	1.00*	1.00*	1.00*

Source: Pollution Prevention and Assessment, Environmental Protection, Environment Canada 2005. Coastal Mills Dioxin and Furan Trend Monitoring Program *www.ecoinfo.ec.gc.ca/env_ind/region/dioxinfuran/dioxin_data_e.cfm#Graph1.*

* Individual loadings not calculated for each mill, but a total dioxin loading of 1.00 mg/day was estimated.

Note: Six mills reported voluntarily before 1991; regulations were not in effect.

ND = Non-detectable 2,3,7,8-TCDD in the effluent.

Table 2. Dioxin and furan concentrations in sediment near coastal BC pulp and paper mill outfalls, 1989–2003 (TEQ*, pg/g).

Mill area	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Crofton	–	237.2	16.1	136.3	27.6	154	157.2	86.6	95.1	71.1	75.8	60.6	68.3	61.7	12.6

Elk Falls	–	10.8	10.9	18.9	1.7	9.7	0.3	–	–	–	4.6	5.3	15.7	16.3	15.3
Gold River	–	972	503.3	584.8	117.5	135.6	112.8	305.1	373.1	337.4	–	–	–	–	–
Harmac	–	380.7	209.7	260.8	310.8	258.6	392.7	216.3	216.9	246.6	108.4	–	–	–	–
Port Alberni	–	76.6	106.4	36.4	35.7	26.8	23.9	28	128.6	–	–	–	–	–	–
Port Mellon	246.2	197.4	198.5	57.4	47.4	109.4	117.6	84.2	95.4	34.3	142.7	20.9	158.9	115.8	82.4
Powell River	–	55.1	69.3	41.5	110.9	33.4	66.4	31.5	19.5	22.8	–	–	–	–	–
Skeena	45.3	–	92.6	45.1	14.1	16.2	21.4	17.3	23.4	14.3	16.2	20.8	11.1	9.3	–
Squamish	84.6	89	19.3	1.9	1	4.6	2.8	2.7	–	–	–	–	–	–	–
No. of mills reporting	3	8	9	9	9	9	9	8	7	6	4	4	4	4	3
Average	125	252	136	131	74.1	83.1	99.5	96.5	136	121	69.5	26.9	63.5	50.8	36.8

Source: Pollution Prevention and Assessment, Environmental Protection, Environment Canada 2005.

* TEQ = Toxic equivalent concentration; used to standardize the total concentrations of the different dioxins and furan congeners to 2.3.7.8-TCDD equivalents.

Table 3. Dioxin and furan concentrations in the hepatopancreas of Dungeness crabs sampled near BC pulp and paper mills, 1989–2003 (TEQ pg/g).

Mill area	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Crofton	–	179.1	82.4	130.2	97.1	49.3	57.1	57.4	29.9	48.5	49.7	34.3	59.3	34.9	28.2
Elk Falls	–	104	116.3	103.8	68.5	63.3	28.1	21.3	14.5	26.1	22.1	17.6	21.8	24.2	30.1
Gold River	–	1075	510	178	59.8	46	17.6	30.7	19.4	45.6	–	–	–	–	–
Harmac	–	228.7	164.1	92.2	22.7	8.2	4.6	15.9	8.9	5.8	–	–	–	–	–
Port Alberni	–	16.2	41.8	52.7	20.2	26.5	57.2	26.9	17.3	–	–	–	–	–	–
Port Mellon[a]	1490	482	196	79.3	143	35.8	67.9	20.9	16.5	12.8	52.2	27.2	35.4	20.1	12.3
Powell River	490	116	78.2	140.2	87.5	2.2	8.5	25.2	14.2	11.4	–	–	–	–	–
Skeena	617	306	344.1	142.4	30.8	30.4	34.8	37	25.9	31.9	57.2	40.0	38.9	33.5	27.3
Squamish[a]	343	67.2	113.2	48.6	24.6	15.6	19.3	12.5	44.6	12.1	Reported with Port Mellon				
No. of mills reporting	4	9	9	9	9	9	9	9	9	8	4	4	4	4	4
Average	735	286	183	107.5	61.6	30.8	32.8	27.5	21.2	24.3	45.3	29.8	38.8	28.2	24.5

Source: Pollution Prevention and Assessment, Environmental Protection, Environment Canada 2005.

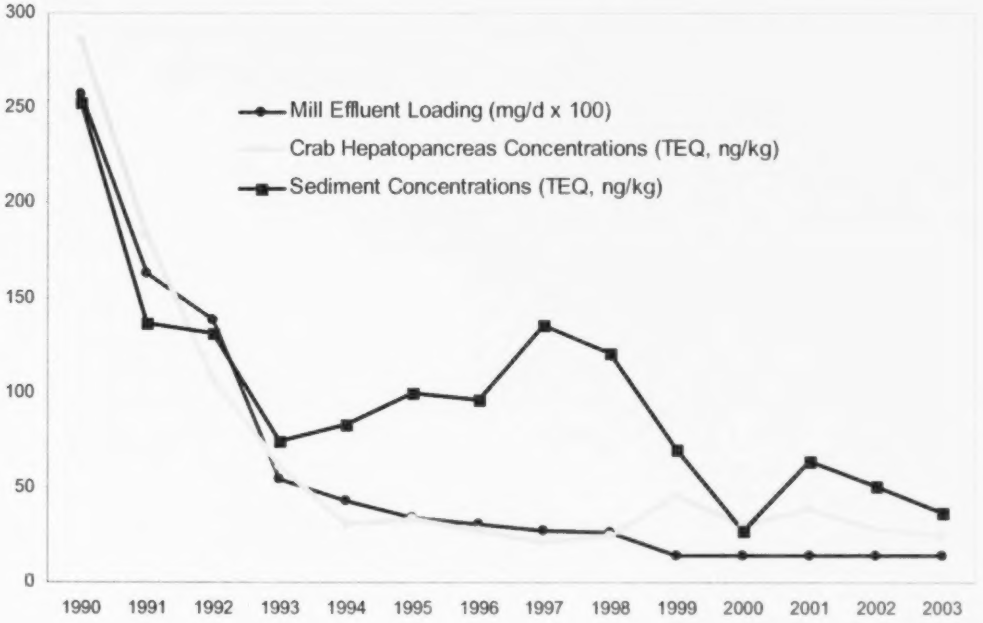
Note: All results are reported in TEQ (toxic equivalent concentration) to standardize total concentrations of dioxins and furan congeners to 2.3.7.8-TCDD equivalents.

[a] Monitoring at the Port Mellon and Squamish mills was combined in 1999 because 2.3.7.8 TCDD was not detected in their effluents and the mills are close together in Howe Sound; after 1996, results for both are reported under Port Mellon.

From 1989 to 2003, dioxin and furan concentrations (TEQ, pg/g) in the sediment near the nine different outfall sites dropped an average of 76% (Table 2). Contamination in the sediment dropped from an average TEQ of 252 pg/g (parts per trillion) in 1990 to 36.8 pg/g in 2003, an overall decline of 85%.

Dioxin and furan concentrations in the hepatopancreas of Dungeness crab declined by 71–97% near the mills that were still reporting data in 2003 (Table 3). Levels went from an average TEQ of 735 pg/g in 1989 to 24.5 pg/g in 2003—an average drop of 96%. Since 1996, the average TEQ in Dungeness crabs near pulp mills has remained near or below the established 30 pg/g guideline for tolerable daily intake.

Figure 2. Total 2,3,7,8-TCDD loadings in pulp mill effluents from all mills reporting at each date, and dioxin and furan concentrations in sediments near the outfall and in crab hepatopancreas, 1990–2003.



Source: Data from Tables 1, 2, and 3).

Note: Number of mills reporting: 9 mills for 1990-1997; 8 mills in 1998; 4 mills for 1999-2003.

Figure 2 displays data from Tables 1 to 3 and illustrates a relationship between the steep decline in dioxin concentrations in mill effluents and the improvement in concentrations in local sediment and crab tissue.

Interpretation

In 1989, the pulp and paper industry began to invest in changes to the bleaching process in response to the concern over dioxin and furan loading in the environment and to address upcoming federal and provincial regulations. Changes in technology included using uncontaminated wood chips and de-foaming agents, new pulp bleaching and washing practices, oxygen-based pulp cooking, and installation of new treatment works. As a result, between 1989 and 1999, there was a 95% drop in total daily loading from all coastal BC pulp and paper mills for 2,3,7,8-TCDD in effluents. After 1999, 2,3,7,8-TCDD was not detectable in the effluent of any mills. At the same time, total daily loadings for the furan 2,3,7,8-TCDF also declined by more than 99% by 2004. Both substances are now present only in minute quantities that fall within federal discharge limits.

The improvement in effluent quality was reflected in a rapid decline in levels of dioxins and furans in the environment (sediments) and local organisms (crabs). Contamination in crabs near outfalls closely tracked the drop in concentrations in effluent, with a decline of 96% from 1989 to 2003. Contamination in the sediment dropped by more than 85% from 1990 to 2003. The decline was not as rapid as in crab tissue, in part because dioxins and furans have a strong affinity for sediments and break down very slowly. Although burial under clean sediment helps to reduce the availability of contaminants, currents, tidal motion, and marine organisms continue to disturb the upper sediment, bringing contaminants to the surface where they can recirculate in the ecosystem.

This indicator shows that coastal BC pulp mills no longer discharge detectable levels of toxic dioxins to marine waters and shows that measures taken to eliminate this source of persistent contaminants in the marine environment have been effective. The continuing low, relatively stable, levels of dioxins and furans in sediments and crab tissue also shows how persistent these chemicals are. It may also indicate that there is a continuing low level of input of dioxins and furans from other sources (e.g., regional incinerators and other local combustion, global atmospheric transport). Given their persistence, low levels of dioxins and furans will remain in the environment for many years.

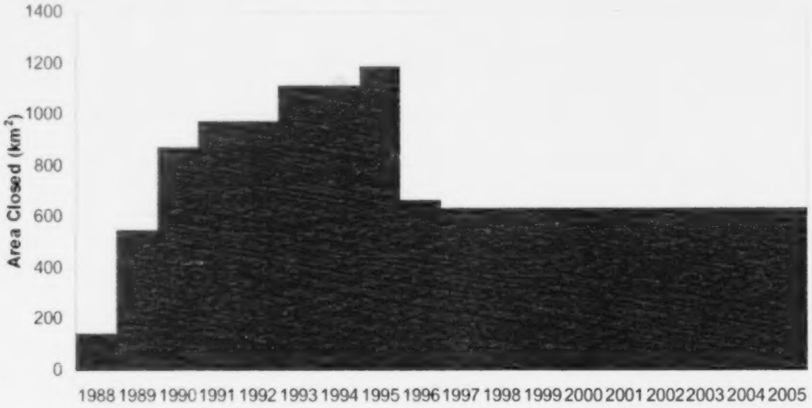
Supplementary Information: Impact of Dioxin and Furan Contamination on Shellfish Harvesting

Fisheries and Oceans Canada closed several areas around pulp mills to shellfish harvesting in 1988 when the health risk from dioxin and furan contamination became known. As monitoring expanded to include more mills, more affected areas were found. By February 1995, nearly 1200 km^2 of BC coastal waters had been closed (Figure 3). The total area closed to shellfish harvesting near eight BC coastal pulp and paper mill locations peaked in 1995.

The sharp decrease in effluent loadings from pulp mills in the early 1990s was followed by a rapid decline in dioxin and furan concentrations in sediments and crab tissue. This made it possible to lift restrictions for all shrimp, prawn, and oyster harvesting in 1995 and later reopen some areas to crab harvesting. More than 46% (550 km^2) of the maximum area closed in 1995 had been reopened by the end of 1997. No restrictions have been lifted since, in part because Health Canada is currently reassessing the safe consumption limits for dioxins and furans.

The remaining shellfish closures prohibit crab harvesting only. The full economic impact of these closures is not known, but the Dungeness crab fishery ranks as one of the most valuable invertebrate fisheries in BC. In 2004, the wholesale value was $67.9 million.

Figure 3. Areas closed to harvesting for crabs, shrimp, oysters, and prawns near eight coastal BC pulp and paper mills, 1988–2005. After 1995, all closures were for crab harvesting only.



Source: W. Knapp, Department of Fisheries and Oceans, Vancouver, 2005.

2. Secondary Indicator: Long-term trends in deposition of pollutants (PCBs, dioxins and furans, PAHs, and mercury) in sediments on the BC coast

This is a pressure and a response indicator. It shows the pressure on the environment from contaminants deposited in sediments, both historically and currently. It also shows the combined effects of industrial, technological, and regulatory changes that have been made to curb contamination from these pollutants.

The indicator addresses the questions: What industrial pollutants are humans releasing into the environment? Are measures to protect the environment from industrial pollutants effective?

Contaminants discussed in this indicator attach strongly to particles and are deposited with the particles as they settle to the bottom. Contaminants can be deposited in sediments close to the discharge point or they may settle after being moved by marine currents (typically over short distances). They may also have been transported in the atmosphere over longer, even global, distances before being deposited in the marine environment.

Methodology and Data

Data from the following sources are presented on the map in Figure 4.

- The surface sediment data came from studies conducted in BC by several investigators between 1993 and 2003 and summarized in a separate review (Burd 2005).
- Data for 17 sediment cores in the Strait of Georgia came from Johannessen et al. (2005a).
- Supplementary unpublished data for PAHs and mercury (e.g., Esquimalt Harbour) came from Environment Canada's Disposal at Sea Program.

The analytical methods used in the above studies were comparable and are expected to produce comparable results for PCBs, dioxins and furans, PAHs, and mercury.

Sediment Sampling

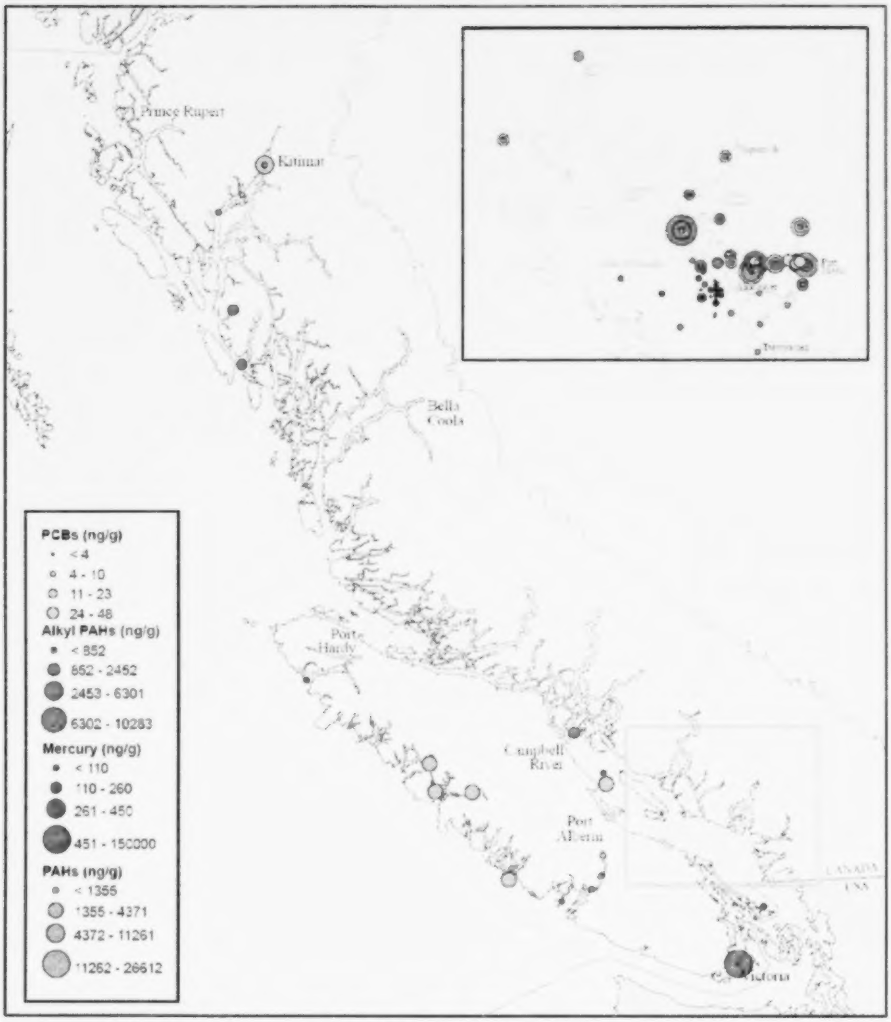
- Grab samplers are used to collect surface sediments. Common models have a set of jaws that shut when lowered into the surface sediments. They usually cover a sampling area of about 0.1 m^2. Chemical analysis is usually done on the top 2 cm of sediment collected. Grabs are most useful for determining the horizontal distribution of pollutants.

Analysis of surface sediment can show spatial variations in sediment contamination but not an accurate time line of historical deposits, even when samples from various dates are compared. This is because organisms living in the sediment mix the top layers to a depth of about 10 cm. Surface grab samples generally represent the upper mixed layer, which, in areas with low deposition rates, can include material from 20 or more years mixed together.

- Core samplers are used to collect a deeper profile of sediments. These samplers penetrate the sediment to a depth of several metres, depending on the sediment characteristics, and provide an undisturbed cross-section. Cores provide more reliable data on the history of contaminant deposition than grab samplers because mixing in the upper layer can be resolved through mathematical modelling of the total profile. Such models typically fit concentration data from the vertical profiles to the measured sedimentation rate for each core. This produces an estimate of the deposition rate or the amount of contaminant deposited per unit of bottom area. The model can then be used to calculate a more accurate estimate of the recent deposition in terms of concentration.

For analysis, sediment cores were sectioned into 1-cm intervals for the top 10 cm, 2-cm intervals for the next 10 cm, and 5-cm intervals for the rest of the core (Johannessen et al. 2005a). The deposition history reflected by the cores ranges from less than 50 years (a site with a high rate of sediment deposition) to more than 140 years (to the 1860s) for sites with lower sedimentation rates. The compiled analyses are portrayed in Figure 4.

Figure 4. Levels of PCBs, PAHs, alkyl-PAHs, and mercury in sediments on the eastern side of the Strait of Georgia [inset] and in other locations on the BC coast.


Prince Rupert
Kitimat
Bella Coola
Port Hardy
Campbell River
Port Alberni
Victoria
CANADA
USA
PCBs (ng/g)
< 4
4 - 10
11 - 23
24 - 48
Alkyl PAHs (ng/g)
< 852
852 - 2452
2453 - 6301
6302 - 10283
Mercury (ng/g)
< 110
110 - 260
261 - 450
451 - 150000
PAHs (ng/g)
< 1355
1355 - 4371
4372 - 11261
11262 - 26612

Source: Burd (2005); Johannessen et al. (2005a,b); Environment Canada's Disposal at Sea program (unpubl. data).

Note: Sites in the classes with the highest level of mercury (>451 ng/g) and highest total PAHs (>11,262 ng/g) exceed levels considered contaminated for pristine (sensitive) sites; some sites in this class also have levels that would not be acceptable in a working harbour, which has higher criteria for contaminated sediments (c.f., BC Environmental Management Act, Contaminated Sites Regulation, Sched. 9, BC Reg. 375/96).

Interpretation

The heaviest industrialization in BC is on the eastern side of the Strait of Georgia, as shown in Figure 4. Sources of contaminants to the Strait currently and historically include pulp and paper mills, municipal and industrial effluents, petroleum refineries, acid mine drainage and mine tailings disposal, aquaculture, agricultural and urban runoff, wood treatment facilities, ships, spills, local combustion, and atmospheric transport from other parts of the globe. Industrial effluents and runoff from agriculture, forestry, and urban areas are also carried into the Strait by rivers. Once in the Strait, depending on their physical properties, contaminants may remain in the water, accumulate in sediments, and/or be taken up by living organisms. Those that remain dissolved are probably flushed out of the Strait within a year (Waldichuk 1983), which helps to prevent their accumulation. Contaminants discussed in this paper have physical properties that favour attachment to sediment particles in water. They end up primarily in sediments and organisms, and thus remain within the local water basin (Johannessen et al. 2005b).

Sediment from the Fraser River is a major influence in the southern Strait. Particles settle and then move northward along the bottom, perhaps driven by the deep, northward return flow of waters that are part of estuary circulation patterns (Johannessen et al. 2005b). Contaminant deposition in sediments within the southern Strait of Georgia is generally higher than it is farther north. This is because sediments accumulate at a higher rate in deep waters of the southern Strait (2.8 cm per year) than at the northern end (0.28 cm per year). Sedimentation rates in the inlets and channels of the Strait and its shallower coastal waters lie between these two extremes (Johannessen et al. 2005a).

PCBs

Sediments are a permanent sink for PCBs because they largely remain in place, with minor degradation, unless the sediment is disturbed (Macdonald and Crecelius 1994). The beginning of commercial production of PCBs in North America in 1929 shows up in sediment cores from the Strait of Georgia. The sediments show a rapid increase in PCB levels starting in the horizon for 1930-40. Concentrations increased to a peak of around 30 ng/g in the 1960s, declining sharply to an average of about 5 ng/g after 1970. This is consistent with the decreasing PCB release to the environment as a result of regulatory controls after 1970.

PAHs and alkyl PAHs

The background level of PAH contamination in sediments in the early 1900s was less than 1 ng/g (ppb). This low level continued through the 1980s in the deep basin of the Strait of Georgia (Macdonald and Crecelius 1994), but had reached 1397 ng/g in the surface mixed layer at the Point Grey disposal site by 2000 (Wilson and McKinnon 2003). Parent and alkyl PAH concentrations in sediments now exceed provincial or interim federal guidelines at most sampling locations in the Fraser River estuary and Vancouver Harbour, as well as in parts of the southeastern Strait of Georgia. Vancouver Harbour has the highest concentrations (Yunker and Macdonald 2003a,b). Analyses show that PAHs in the southeastern Strait of Georgia came primarily from the Main and North arms of the Fraser River, and from sediment dredged from Vancouver Harbour (Yunker 2000). As shown on Figure 4, some of the total PAH levels are above 10,000 ng/g, which is the criterion for sensitive estuarine sediments as defined in the BC Environmental Management Act (Contaminated Sites Regulation, Schedule 9, BC Reg. 375/96). Some are also above 20,000 ng/g, which is the contaminated sites criterion for typical marine sediments, such as in a working harbour.

Mercury

The Fraser River is the main source of mercury (about 75%) deposited in the Strait of Georgia. Local, "point" sources, such as a former chlor-alkali plant, pulp mills, mine tailings, shipyards, and municipal outfalls are also important in smaller geographic areas.

The pre-industrial, background concentration of mercury in the Strait appears to have been 60 ng/g (ppb) or less (Johannessen et al. 2005a). By 1900, Vancouver Harbour had a mercury concentration of 300 ng/g. The sediment record shows peaks in mercury contamination from placer gold mining along the Fraser River in the 1860s, from mercury mining in the Fraser basin during World War II, from a chlor-alkali plant at the head of Howe Sound (1965-1970), and from bleaching processes in pulp mills around the Strait before chlorine was introduced in the 1960s. In addition, a mercury contamination event from an unknown source deposited sediment containing 230,000 ng/g in Port Moody Arm around 1970. This was enough mercury to poison the organisms on the bottom and halt biological mixing of sediments for about 20 years (Johannessen et al. 2005a).

Recent measurements from a variety of studies suggest that surface mercury concentrations are lowest in the central Strait and near the mouth of the Fraser River (10–154 ng/g), and highest in Port Moody Arm (77–420 ng/g), Burrard Inlet (230–250 ng/g), False Creek (399 ng/g), and Howe Sound (150–500 ng/g) Concentrations of 180–31,800 ng/g have been found in Esquimalt Harbour, with Victoria Harbour showing up to 2760 ng/g, reflecting a variety of industrial sources (Garrett 2004). These concentrations range from well below, to well above, the effects threshold used by CCME, which is 130 ng/g for mercury (0.13 mg/kg) (CCME 1999). To put these concentrations in context, the criteria for contaminated sites under BC Environmental Management Act is 430 ng/g of mercury for sensitive estuarine sediments and 840 ng/g for typical harbour sediments. With respect to Georgia Strait sediments, Johannessen et al. (2005a) stated that it is likely that mercury concentrations will remain above the threshold for effects on benthic organisms for many years.

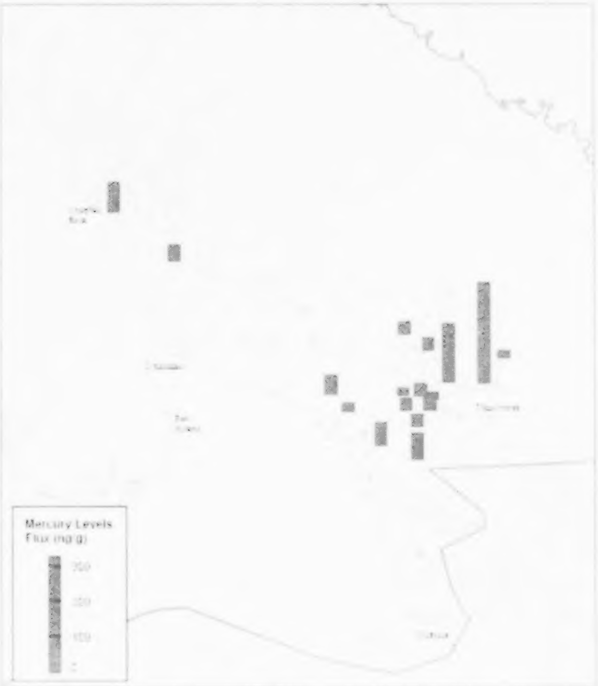
Supplementary Information: Mercury Deposition Rates in the Strait of Georgia

The interpretation of sediment data provides no indication that mercury contamination is declining in marine sediments, although Johannessen et al. (2005a) recently found a trend toward lower deposition of mercury throughout the Strait of Georgia.

Geographic differences in local sedimentation and mixing rates mean that the spatial variation in mercury concentrations (Figure 4) does not directly reflect the rate at which mercury is deposited (Figure 5). In areas where the sedimentation rate is high, dilution by clean sediment acts to lower the measured concentration of mercury. In areas where the sedimentation rate is low, continued mixing of the upper sediment by marine organisms keeps the mercury concentration higher at the surface, even though there may no longer be local sources. In particular, the concentration of mercury near the mouth of the Fraser River is low because the mercury carried by the river is diluted by a large volume of other, uncontaminated particles (Johannessen et al. 2005a).

Although the Fraser River is the main present-day source of mercury to the southern Strait of Georgia, contributing about 75% of the total mass deposited annually, the situation is reversed in Vancouver Harbour. There, industrialization and other human activities account for at least 75% of the annual deposition (Johannessen et al. 2005a). Direct atmospheric deposition to the Strait of Georgia is currently only 2% of the quantity annually deposited by the Fraser River, but this figure may increase. Mercury can be transported long distances in the atmosphere and some of the atmospheric deposition originates with the combustion of fossil fuels, particularly coal. The growing demand for energy in Asia threatens to increase the concentration in the atmosphere over BC, which lies downwind (Pacyna and Pacyna 2002). This would increase the amount of mercury deposited directly to BC's coastal waters from the atmosphere and indirectly by the Fraser River.

Figure 5. Modelling of recent mercury deposition rates in the Strait of Georgia.



Source: Johannessen et al. 2005a. (Flux = amount of mercury flowing over a given area per unit time).

3. Secondary Indicator: Clean-up of contaminated sites in BC

This is a response indicator showing a societal response to the problem of industrial contamination. It addresses the question: What is being done about environmental contamination?

An area is considered contaminated if the site is unsuitable for specified land or water uses. Such sites may have become contaminated through spills or through deposits of chemicals during the course of commercial and industrial activity. At some locations, toxic substances in soil, surface water, and groundwater are a threat to the environment and human health. Contaminated sites can release toxic substances into the surrounding environment, infiltrating the food chain, entering the ground water, and contaminating neighbouring areas. Many sites were contaminated by past activities, up to a century or more ago, before the impact of such activities was known. Some land around Victoria's inner harbour, for example, was contaminated with metals and PAHs by a coal gasification plant in the late 1800s.

The contamination affects both land and water, and the size of contaminated sites ranges from less than a hectare to several square kilometres. The largest single source of site contamination in BC has been activities related to fossil fuels and vehicles, such as petroleum and natural gas storage and distribution, and vehicle salvage and wrecking. Heavy metals such as lead, arsenic, cadmium, and mercury are also common at contaminated sites in BC. Organic chemicals, including benzene and toluene from gasoline, occur at about two-thirds of the sites. Chlorophenols are found where wood treatment operations took place, as are benzo[a]pyrene and naphthalene from creosote. PCBs often occur at sites where heavy electrical equipment was used.

With the exception of federally managed sites, the BC Ministry of Environment is responsible for managing contaminated sites in the province and ensuring that site managers meet cleanup requirements to restore damaged lands to standards set out in the BC Environmental Management Act. These include requirements for protecting human health and improving ecosystem health by reducing or eliminating toxic materials and performing other activities to return land to a condition suitable for more general use.

Methodology and Data

The BC Ministry of Environment has been collecting information on contaminated sites since 1988. The Contaminated Sites Registry was created in 1997 to provide public access to current information on which sites are, or were, contaminated and the status of the clean-up or remediation on the site.
www.env.gov.bc.ca/epd/epdpa/contam_sites/sites_info/index.html.

Note that not all of the sites in the Registry are necessarily contaminated. Some were found to be clean after they were registered, others were contaminated at one time but were remediated before being entered in the Registry. The Registry also contains sites awaiting complete assessment, for which the degree of contamination has not been determined.

Not all contaminated sites in the province have been submitted to the Sites Registry. Local governments, for example, can opt out of the registry program but must register a site if remediation is under way or if it is being decommissioned. Contaminated sites under federal jurisdiction (e.g., on federal Crown land) are also managed separately, but 268 of the 320 federally managed sites in BC (as of April 2005) are included in the provincial Sites Registry.

For this indicator, the set of all contaminated sites in the Ministry's three coastal regions (Vancouver Island, Lower Mainland, Skeena) was obtained from the Registry records. The proportion of the total sites was determined for which remediation is complete, in process, or for which a complete assessment is pending (Table 4 and Figure 6).

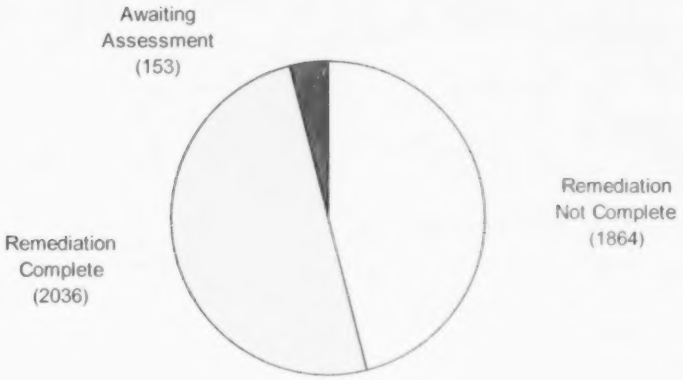
As of April 2005, 6578 sites were registered in the whole province, of which 4053 (61.6%) were in the Ministry's three coastal regions (Table 4). More information on provincial contaminated sites regulation is available at *www.env.gov.bc.ca/epd/epdpa/contam_sites/*.

Table 4. Number of sites in three coastal regions listed in the BC Ministry of Environment Sites Registry by remediation status (as of April 2005).

	Vancouver Island	Lower Mainland	Skeena	Total
Remediation complete	446	1517	73	2036
Remediation not complete	501	1101	262	1864
Awaiting complete assessment	29	74	50	153
Total	976	2692	385	4053

Source: BC Environment, Contaminated Sites Registry, April 2005.

Figure 6. Remediation status of contaminated sites in the coast region of BC.



Source: Data from BC Ministry of Environment Contaminated Sites Registry.

Interpretation

A total of 4053 contaminated sites have been registered in the Ministry of Environment's three coastal regions (Vancouver Island, Lower Mainland, Skeena). There is no way to know how many, as yet unregistered, contaminated sites exist in the province; however, since the registry started, 2036 sites in the coastal region have been remediated, and almost that number are in the process. In recent years, about 200 sites per year have been remediated.

Most coastal contaminated sites are located in highly populated areas: 66% in the Lower Mainland, 24% in Vancouver Island Region, and 10% in the Skeena Region. Of these sites, cleanup has been completed at 50%, and is under way at a further 46%. The remaining 4% of sites are awaiting assessment, and the degree of contamination and need for remediation is not known. In total, 96% of the contaminated sites in BC's coastal regions that were registered in the Sites Registry have been or are in the process of meeting cleanup requirements under the BC Environmental Management Act. In comparison, about 85% of the known contaminated sites in the rest of the province have been cleaned up or are in the process of remediation.

4. Key Indicator: Persistent organic pollutants in tissues of marine mammals on the BC coast

This is a pressure indicator showing the accumulation of persistent contaminants in the body tissue of whales, seals, and other organisms. It addresses the question: What is the extent of contamination from persistent organic pollutants (POPs) in the coastal environment?

POPs enter the marine food chain when organisms at the bottom of the food web, such as plankton, accumulate the contaminants from water, sediment, and food. Bottom-dwelling species with free-swimming larval stages can act like a biological "pump," moving POPs from the sediment into the water column above, where the larvae are eaten by fish. POPs are fat soluble and persistent; therefore, through biomagnification, the tissue contaminants become more concentrated as they move up the food chain to seals and killer whales (Ross et al. 2000, 2004).

Marine mammals can serve as indicator species for the presence and extent of environmental contamination because they feed high on the marine food chain. The level of contaminants in their bodies may also indicate risks to human health, especially for people who consume large amounts of fish and shellfish (Ross and Birnbaum 2003).

This indicator reports on levels of POPs in three groups of killer whales (*Orcinus orca*) inhabiting the BC coast (transients and the southern and northern populations of resident killer whales) and on harbour seals (*Phoca vitulina*). The transient whales are predators on other marine mammals, whereas both resident whale populations mainly eat fish. Because coastal killer whales travel and feed over a large area (and it is not known where they spend the winter), contaminants found in their tissues may reflect the general state of contamination in the Pacific Ocean ecosystem.

In contrast, harbour seals are year-round residents on the coast and occupy relatively small ranges of about 20 km^2 (Cottrell et al. 2002), making them better indicators of contamination at a local-to-regional scale. Two of their preferred food fish, herring and hake, can be migratory, so there may be some influence on contaminant concentrations in harbour seals from sources outside the seals' immediate range (Ross et al. 2004).

Methodology and Data

Killer Whale Samples

Blubber samples were collected with biopsy darts from killer whales of both sexes and various ages in the three coastal populations. PCBs, dioxins, and furans were analyzed using high-resolution gas chromatography/high-resolution mass spectrometry (Ross et al. 2000). A slightly different grouping drawn from the same original sample set was analyzed later for PBDEs (Rayne et al. 2004). The identity of each individual sampled was confirmed using a photo identification database containing all resident and many transient whales. This provided demographic information and ensured that the same whale was not sampled twice.

Harbour Seal Samples

Tissue samples from harbour seal pups were collected in 1996 from four locations in the Strait of Georgia (Victoria, Vancouver, Crofton, and Hornby Island) and from Queen Charlotte Sound. The concentration of POPs in harbour seals increases with age, especially in males. Therefore, by sampling only pups, researchers could ensure that subjects were all the same age (three to six weeks) and that virtually all of the contaminants carried by pups come from their mothers through the placenta and in milk (Ross et al. 2004).

Total PCBs and total PBDEs in blubber of killer whales of various ages and harbour seal pups are summarized in Table 5 and shown in Figure 7.

Total PCBs, dioxins and furans in seals and northern resident killer whales are shown in Figure 8.

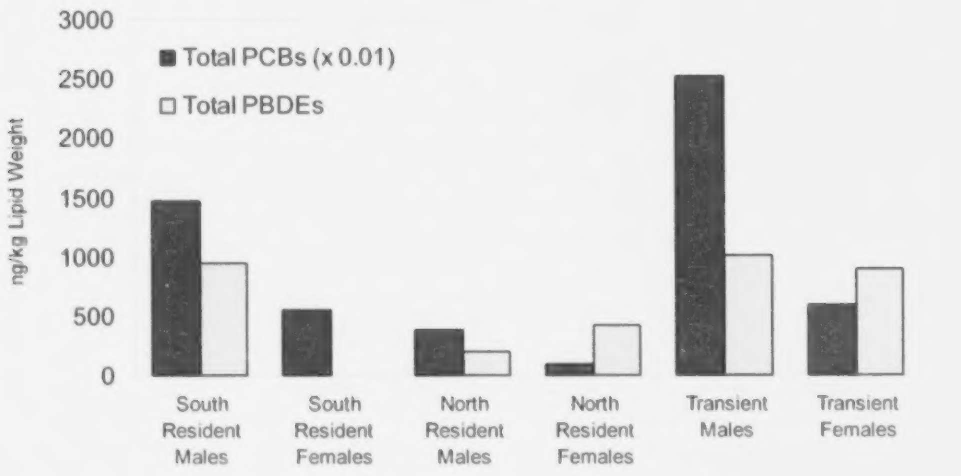
Table 5. Total PCBs and PBDEs in the blubber of killer whales of various ages and harbour seal pups (3–6 weeks old) on the coast of BC.

Species	Population sampled	Total PCBs (ng/g)		Total PBDEs (ng/g)		Data source
		Mean (n)	SD	Mean (n)	SD	
Killer whales	S. resident males	146,300 (4)	32,700	942 (5)	291	PCBs: Ross et al. 2000
	S. resident females	55,400 (2)	19,300	–	–	
	N. resident males	37,400 (8)	6,100	203 (13)	58	PBDEs: Rayne et al. 2004
	N. resident females	9,300 (9)	2,800	415 (8)	338	
	Transient males	251,200 (5)	54,700	1,015 (6)	302	
	Transient females	58,800 (5)	20,600	885 (7)	353	
Harbour seals (pups)	Strait of Georgia	2,475 (31)	174	–	–	Ross et al. 2004
	Queen Charlotte Sound	1,143 (5)	262	–	–	

Note: Concentrations are in ng/g (ppb) lipid weight. PCB data on whales are for adults only; PBDE data for whales include some juveniles.

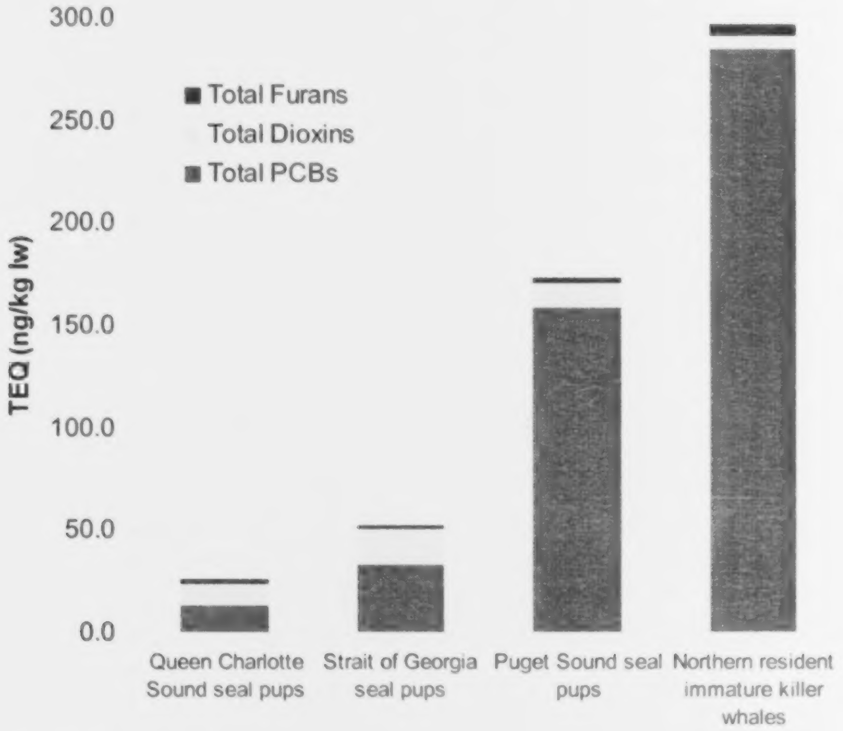
Note: Large variances about the means (SD = standard deviation) are due to the wide age range in whales sampled as well as the small sample sizes.

Figure 7. PCB and PBDE concentrations (ng/kg lipid weight) in male and female killer whales from three populations (southern and northern residents, transients).



Sources: Compiled from Rayne et al. 2004 and Ross et al. 2000, 2004.

Figure 8. Total equivalent concentrations (TEQs) of PCBs, dioxins, and furans in harbour seal pups from Queen Charlotte Sound, Strait of Georgia, and Puget Sound and immature northern resident killer whales (ng/kg lipid weight).



Source: Ross et al. 2000.

Interpretation

Differences in tissue contamination between the three groups of killer whales were consistent with differences in their diet and geographic range. Transient whales were the most contaminated, likely because they feed at a higher trophic level by consuming other marine mammals. Transients are wide-ranging and do not appear to frequent the more industrialized areas of the coast, therefore it is not likely that they occupy more contaminated waters than resident whales.

Although PCB concentrations in northern resident whales were high compared to marine mammals from other parts of the world, they were the least contaminated of the three BC groups of whales. Although they have a similar diet, the more contaminated southern population likely eats more contaminated prey from the industrialized areas of BC and Washington state (Ross et al. 2000). The health risk to killer whales of this concentration of contaminants is not known, but they are among the most contaminated marine mammals in the world (Ross et al. 2004). A high tissue concentration of PCBs was one reason for the recent classification of southern resident killer whales as Endangered under Canada's Species at Risk Act.

These studies show that PCB concentrations in killer whales are roughly 100 times higher than PBDE concentrations (Rayne et al. 2004), likely reflecting the earlier period of use of PCBs relative to PBDEs. PCBs may also accumulate to a greater extent because PCB molecules are smaller than PBDE molecules, and small size favours more rapid uptake. The most common PBDE congener, BDE-47 (one of the more toxic forms of PBDE), accounts for about 60–75% of the PBDEs in killer whales (Rayne et al. 2004) and is widely distributed in environmental samples (Gill et al. 2004). In all three killer whale populations, males were more contaminated with PCBs (but not PBDEs) than females. This is consistent with the fact that females shed some of their body burden of POPs through the birth and lactation of each calf, whereas males would continue to accumulate contaminants throughout their life.

As shown in Figure 8, accumulated PCBs appear to be more of a risk for harbour seal pups than dioxins and furans. There were differences in tissue concentrations between seal pups born in Queen Charlotte Sound, the Strait of Georgia, and Puget Sound. It appears that contamination in the diet of adult harbour seals is reflected in regional differences in contamination of their pups, with the order of contamination being Puget Sound > Strait of Georgia > Queen Charlotte Sound (Ross et al. 2004). This is consistent with the finding that herring from the Southern Strait of Georgia have lower contaminant concentrations than herring from the central and southern portions of Puget Sound (O'Neill and West 2005).

The burden of mixed contaminants can impair the immune system in seals, possibly facilitating outbreaks of disease and mass mortality (de Swart et al. 1996). Although the health risk to whales from these contaminants is unknown, concentrations in most whales were higher than those likely to cause immunotoxicity in harbour seals (Ross et al. 2000). Research has shown that Vitamin A concentrations in harbour seals in the Strait of Georgia and Puget Sound has been affected by exposure to contaminants (Simms et al. 2000), whereas contaminant concentrations in Strait of Georgia animals are still below those likely to cause immunotoxicity (Ross et al. 2004).

Few data are available on contaminant trends over time in BC's marine mammals, but the PCB concentrations in harbour seals from southern Puget Sound dropped rapidly after controls on the release of PCBs were imposed in 1970s. Levels stabilized after the mid-1980s (Ross et al. 2004), reflecting the persistence of PCBs already in the environment, continued seepage from old sources, and new inputs through atmospheric delivery from distant sources.

Overall, this indicator shows that POPs released in the environment continue to accumulate through the food webs and recycle in ecosystems long after measures intended to curtail emission from industrial sources have taken effect. POPs, such as PCBs, dioxins, and furans, that have been the target of regulation and pollution control efforts for decades, are still accumulating in whale and seal tissues. Adding to the tissue contamination of "legacy" POPs, are the PBDEs, which appear to have been accumulating within the marine food chain since the 1970s. They have emerged only recently as an environmental concern, in much the same way that PCBs were considered 30 years ago.

POPS IN A TERRESTRIAL MAMMAL: GRIZZLY BEAR

A recent study of grizzly bears in BC found that the coastal bears carry more POPs in their tissues and have a different group of contaminants than the grizzlies that live in the interior (Christensen et al. 2005). Spawning Pacific salmon make up a large proportion of the fall diet of coastal bears, whereas the diet of interior grizzlies consists mainly of plant material with no salmon.

The salmon diet of coastal bears was found to be the source for about 80% of the PBDE congeners, 90% of the PCBs, and 70% of the organochlorine pesticides found in the body tissue of the bears. Although levels of contaminants in the bears were low and it is not known what effect this might have on their health, the study does show the significance of salmon as a transport for contaminants from the North Pacific Ocean.

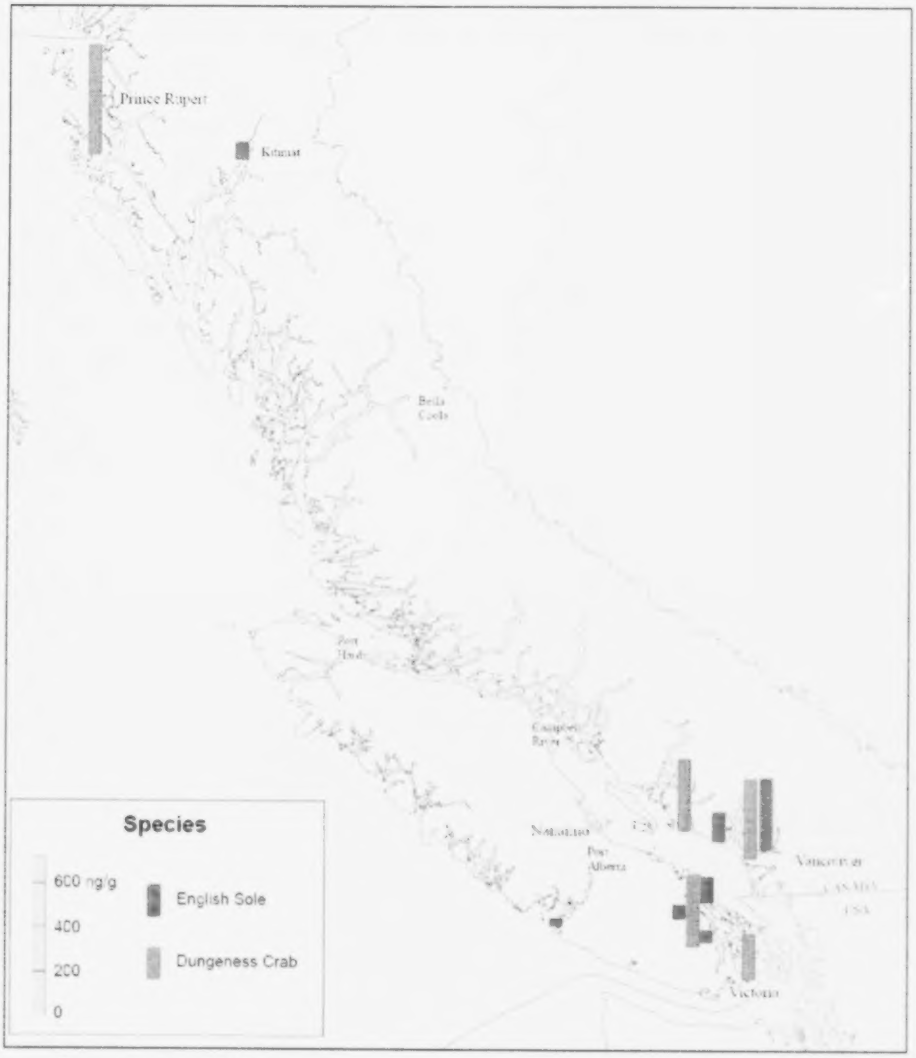
Supplementary Information: PBDEs in other organisms

PBDE levels are rapidly increasing worldwide as a consequence of exponential increases in production (Ikonomou et al. 2002). In North America, the environment and people are 10 or more times as contaminated with PBDEs as in Europe, and studies show that the level of contamination has doubled every 4-6 years (Hites 2004). An assessment of harbour seal "food baskets" (20 species of prey) showed that PBDEs are now ranked as the number three POP in the Strait of Georgia food web, after PCBs and DDT (Cullon et al. 2005).

In BC, studies on the PBDE concentrations in animals from the Strait of Georgia between 1991 and 2000, show variable results, in part because concentrations in the environment have been increasing over the period the samples were collected (Figure 9). Ikonomou et al. (2002) report:

- Dungeness crab collected from sites in the Strait of Georgia and at Kitimat and Prince Rupert had 4–420 ng/g lipid weight in tissues of their hepatopancreas.
- English sole collected from the same areas and time period had 22–310 ng/g lipid weight in the liver tissue.

Figure 9. PBDE concentrations (ng/g lipid weight) in tissues of Dungeness crab and English sole in coastal samples.


Prince Rupert
Kitimat
Bella Coola
Port Hardy
Campbell River
Nanaimo
Port Alberni
Vancouver
CANADA
USA
Victoria
Species
600 ng/g
400
200
0
English Sole
Dungeness Crab

Source: Ikonomou et al. 2002.

5. Secondary Indicator: Long-term trends in persistent organic pollutants in great blue heron and cormorant eggs

This is a pressure indicator and in some respects a response indicator. It shows the pressure from POPs in the environment on key marine bird species, while also showing the effects of societal efforts to respond to the problem. It addresses the questions: What is the impact of persistent pollutants in the environment? Are efforts to protect the environment from industrial pollutants effective?

Herons and cormorants can be used as indicators of the health of the coastal environment because they occur over a wide geographic range. They also feed primarily on small forage fish whose contaminant levels reflect local conditions. The coastal populations of herons do not migrate, and cormorants do not migrate outside the region.

Since herons and cormorants feed mainly on small fish, any changes in the amount of contaminants entering the food chain are rapidly reflected in contaminant levels in their prey, and subsequently in bird eggs. Spatial and temporal patterns in environmental contamination can be evaluated by measuring contaminant concentrations in eggs.

Methodology and Data

The Canadian Wildlife Service began monitoring toxin levels in the eggs of great blue herons (*Ardea herodias*) in 1977 and double-crested cormorants (*Phalacrocorax auritus*) in 1970. Environment Canada has used these data from the Georgia Basin to establish an indicator of contamination in birds that feed higher on the food chain (c.f., Environment Canada 2005a,b,d).

More than 20 great blue heron colonies were sampled, beginning in the 1980s. Three colonies, located in the Georgia Basin, were chosen for in-depth monitoring. The University of British Columbia colony reflected general non-point source urban pollution; the Nicomekl colony represented a rural habitat, and the Crofton colony reflected point-source pollution from a pulp and paper mill. Samples were maintained in a tissue bank, which allowed them to be reanalyzed and trends to be assessed retrospectively as new contaminants were identified. Compounds for analysis have included industrial organochlorines (PCBs, dioxins and furans, and PBDEs) and organochlorine pesticides (DDE, chlordane, dieldrin).

Data were obtained from eggs sampled by the Canadian Wildlife Service. No more than one egg was removed from any nest. The egg contents were placed in glass jars with a chemically cleaned foil liner between the lid and jar, or wrapped in aluminum foil and then frozen until analysis.

In some years, eggs from individual colonies were pooled before analysis by combining equal volumes from each egg to make one sample. In other years, individual eggs were analyzed (Elliott et al. 2001; Turle and Collins 1992).

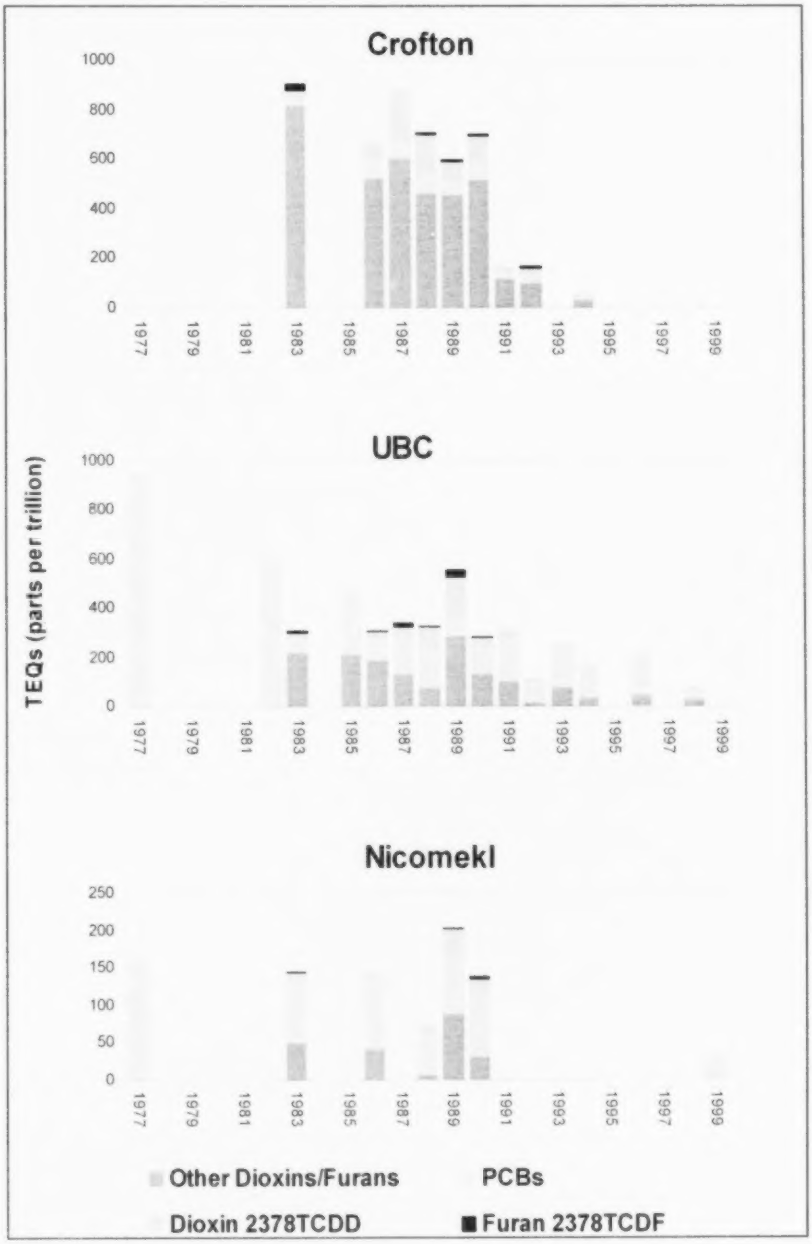
The levels of contaminants were determined by Environment Canada's national laboratories, using methods of the period. Conversion factors were used to compare early concentrations with later values to take into account refinements in analytical methods over the period these data were collected. For example, conversion factors were applied to concentrations of PCBs measured as PCB 1260 (early 1970s) and PCB 1254/1260 (1973–1987) to convert them to the sum of PCB congeners (after 1987). After 1987, total PCBs were measured as the summed concentrations of the individual congeners present.

Concentrations of PCBs, dioxins, and furans are displayed as toxic equivalent concentrations (TEQs) on a wet weight basis, derived using standard conversion factors. (Note: these TEQs are not strictly comparable to data reported in the previous indicator for marine mammals, which were based on lipid weight).

Figure 10 shows the different patterns of contamination with PCBs, dioxins, and furans in the eggs of the three test colonies of great blue herons. The levels of the most toxic dioxin (2,3,7,8-TCDD) and furan (2,3,7,8-TCDF) congeners are shown separately along with the total other congeners of dioxins and furans.

Figure 11 shows the levels of contamination in the three colonies from three organochlorine pesticides that are no longer in use in Canada: DDE (breakdown product of DDT), dieldrin, and chlordane.

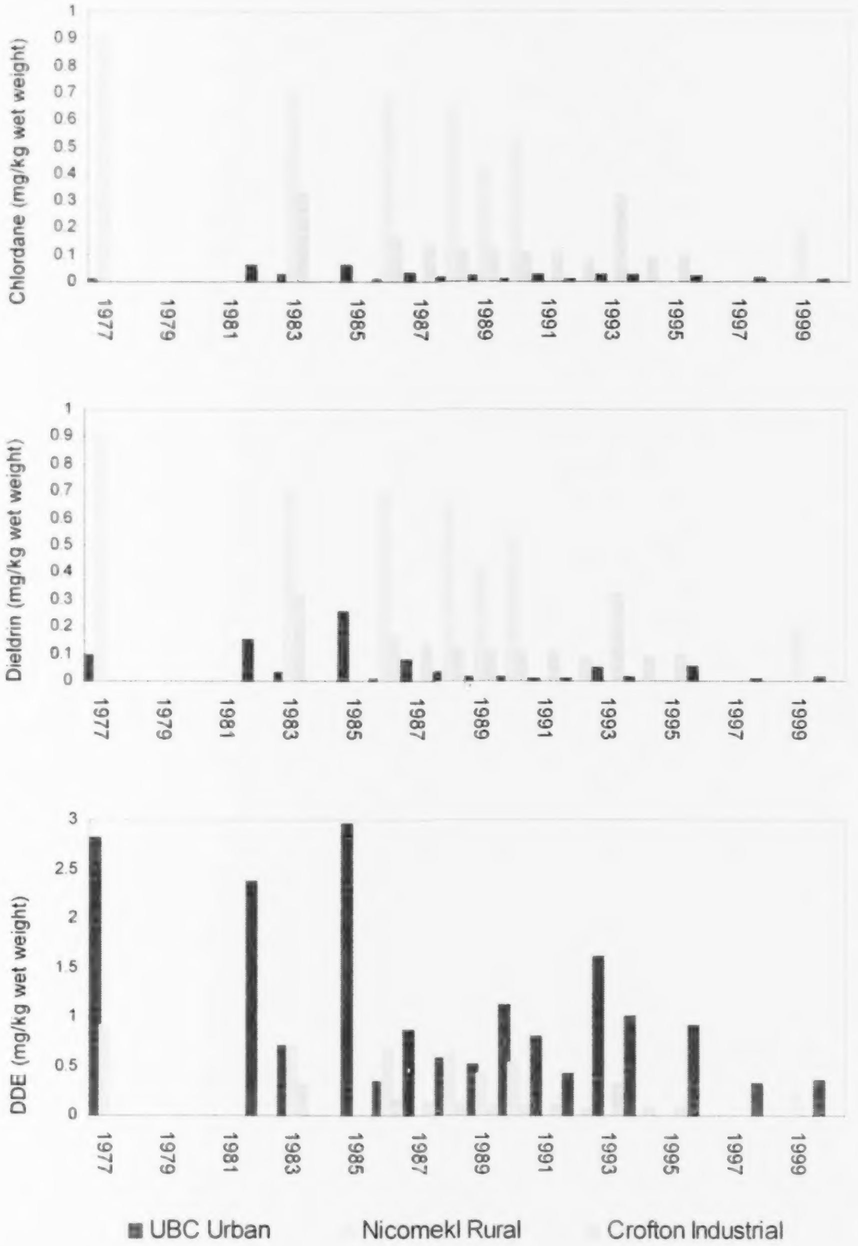
Figure 10. Pattern of toxic equivalents (TEQs in parts per trillion, ppt, wet weight) of industrial organochlorines in great blue heron eggs from colonies at UBC, Nicomekl, and Crofton.



Source: Canadian Wildlife Service (Environment Canada 2005b).

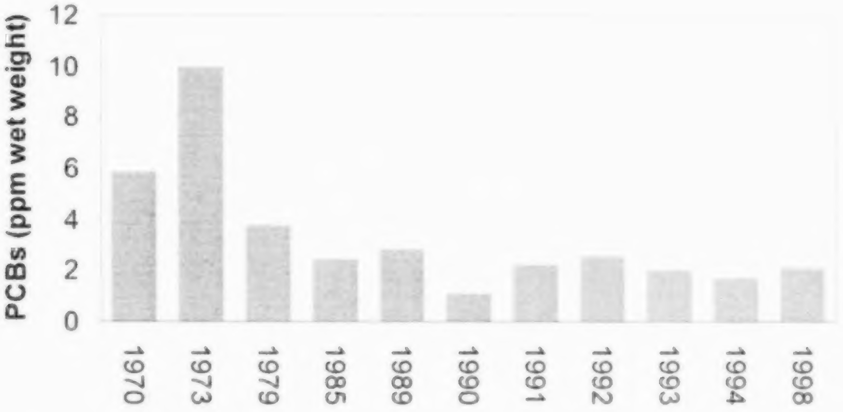
Note: Only PCBs were measured in 1977 and 1982 at UBC; in 1977 at the Nicomekl colony.

Figure 11. Concentrations of organochlorine pesticides (mg/kg wet weight) in great blue heron eggs from the Georgia Basin (UBC, Nicomekl, and Crofton).



Source: Environment Canada 2005b.

Figure 12. PCBs in double-crested cormorant eggs from Mandarte Island (southern Strait of Georgia) (parts per million, ppm, wet weight of PCBs). Values are arithmetic means of the sum of all PCB compounds.



Source: Canadian Wildlife Service 2000 (Environment Canada 2005d).

Interpretation

PCBs, Dioxins, and Furans

Monitoring shows that PCB, dioxin, and furan concentrations have been decreasing in heron eggs (Figure 10) since the late 1970s and early 1980s. Until 1990, the Crofton heron colony was most contaminated by dioxins and furans coming from the nearby (point source) Crofton pulp and paper mill. The UBC colony, which forages in the Fraser River estuary, showed more exposure to PCBs, which would originate from a variety of non-point and point sources. These differences in pattern reflect differences in local impact between a pulp mill and a large urban centre. The lower levels of contaminants from the rural colony (Nicomekl) is consistent with what would be expected for a colony exposed to lower deposition of POPs overall.

The double-crested cormorant colony at Mandarte Island, in the southern Strait of Georgia, shows a similar history of PCB exposure (Figure 12). The mean concentration in eggs fell from 10 mg/kg wet weight in 1973 to less than 2 mg/kg in 1998. This colony occupies a larger geographic range than the UBC herons, feeding over most of the Strait of Georgia and Puget Sound in the fall and winter. The contaminant levels in their eggs would indicate broader contaminant levels over the region.

In 1987, studies on the impact of elevated dioxin and furan concentrations on heron chick development found that the Crofton heron colony failed to produce chicks and had very high dioxin/furan toxicity in their eggs (Elliott et al. 2001). In 1988, embryos and chicks had significantly higher levels of organochlorine detoxifying enzymes in their livers, reduced growth rates, and other signs of dioxin exposure (e.g., Hart et al. 1991). Reproductive success improved in later years at the Crofton colony. This is likely related to the decrease in levels of dioxin/furan concentrations in the eggs coincident with the sharp drop in dioxin and furan releases from the Crofton pulp mill after 1989 (see Table 1, Indicator 1) (Sanderson et al. 1994).

The drop in PCB concentration in the eggs coincides with the timing of controls on PCB release in North America, starting in 1977. The relative contribution of dioxins and furans to the total TEQ has decreased substantially in response to these restrictions. Residues continue to persist, however, from past deposition and ongoing atmospheric deposition of PCBs (Wilson et al. 1996). Added to the residues from older POPs released into the environment is the more recent threat of PBDEs, with concentrations increasing rapidly in the eggs of both herons and cormorants (Elliott et al. 2005). Mean concentration of PBDEs were 455 ng/g wet weight in the heron eggs from the UBC colony in 2002. At some locations, concentrations of the most toxic PBDEs (the penta-dibromodiphenyl ether forms) in fish are approaching levels potentially toxic to fish-eating birds (Elliott et al. 2005).

Organochlorine Pesticides

Monitoring shows that concentrations of DDE, dieldrin, and chlordane have been declining over time in heron eggs (Figure 11). As with the industrial contaminants described above, there were local differences in concentration. The lowest concentrations were in the Crofton colony, which would be expected because these pesticides were not typically used in, nor are a product of, pulp mill processes. The greatest concentrations of all chemicals were in eggs from the UBC colony, representing urban non-point sources. All of these pesticides originally had urban uses for insects in buildings as well as in horticultural and agricultural areas.

In birds, the impact of organochlorine pesticides is apparent in thinner eggshells, which are easily damaged, lowering reproductive success. Studies on heron eggs showed that shells were consistently thinner between 1977 and 1986 than they were before 1947; shell thickness also has increased at all three colonies (UBC, Crofton, and Nicomekl) since 1987 (Harris et al. 2002), which coincides with the general reduction in input of these pesticides to the environment.

The decline in chlorinated pesticide concentrations in heron eggs reflects legislation banning or severely restricting Canadian production and use. Permits for the use of chlordane were suspended in 1985, with the exception of use to control subterranean termites (discontinued in 1995). The sale of dieldrin was heavily restricted in the mid-1970s, with its last registered use in Canada in 1984. Although DDT was banned in 1969, the breakdown product, DDE, is still present in wildlife at toxicologically significant concentrations. These residues likely come from atmospheric transport from regions where DDT is still used for insect control, as well as from persistent residues in BC soils and sediments from past agricultural use.

Supplementary Information: Pesticides in the Lower Fraser Valley

Pesticides are used to control or eliminate insect pests, weeds, and fungi in the forestry, agricultural, and urban landscapes. Active ingredients in pesticides range from non-toxic to extremely toxic; some are active only at the time of application (e.g., soaps and horticultural oils), others persist for months or more in the environment. In 2003, the most recent year for which statistics are available, 999,767 kg of pesticide active ingredients were sold or used in BC (not including wood treatment chemicals or most domestic-label products; ENKON 2005).

In 2003, studies conducted by Environment Canada detected 34 currently used pesticides in air samples near Abbotsford in the lower Fraser Valley. Although use of most organochlorine pesticides (which are POPs) has been restricted, both lindane and endosulfan remain in use and were detected at low concentrations along with several organochlorine pesticides that are no longer used. Endosulfan peaked at 380 pg/m^3 during the summer, at around the time it was applied to crops.

Other, non-chlorinated, but persistent pesticides found were the herbicide atrazine and the organophosphate insecticide malathion. Atrazine peaked at 150 pg/m^3 in air but was not detected in rainwater. Malathion was present at the highest concentration, 2500 pg/m^3. Atmospheric concentrations of both malathion and atrazine at Abbotsford were the highest measured across Canada in 2003 (Blanchard et al. 2005).

WHAT IS HAPPENING IN THE ENVIRONMENT?

A wide range of contaminants are detectable in BC's coastal environment, originating from a variety of human activities. The contaminants described in the indicators included PCBs, dioxins and furans, PBDEs, mercury, and DDE, all of which are persistent and bioaccumulative, and PAHs and some organophosphorus pesticides, which are less persistent. Many of the contaminants were discharged locally into the environment in the past, through practices that are socially and legally unacceptable today, but which were widespread during the first half of the last century.

Overall, the environmental concentrations of PCBs, dioxins and furans, mercury, DDE, and other organochlorine pesticides have fallen. This is a direct result of regulatory controls on release of these substances to the environment that were instituted in the 1970s–1990s. Except at contaminated sites, the concentrations found in the air, water, and general environment are low. Through bioaccumulation and biomagnification, however, much higher concentrations of persistent chemicals appear in animals near the top of the marine food chain, such as marine birds, seals, and killer whales.

PCBs, dioxins, furans, and some pesticides are called "legacy POPs" because residues remain in the environment long after actions were taken to eliminate the main commercial and industrial sources of these chemicals. For animals at the top of the marine food chain, PCB residues are still the most toxicologically significant of all POPs, even though almost 30 years has elapsed since release of PCBs was prohibited throughout North America. Residues of DDE are still significant more than 35 years after DDT was banned in Canada. These POPs will persist in the coastal environment for decades, gradually diminishing in toxicological importance until they reach equilibrium with new inputs.

PBDEs represent a new class of persistent contaminants that have become a focus of concern within the last 5–10 years because levels in the environment have been rising rapidly. PBDE concentrations in the breast milk of Vancouver area mothers doubled every two and half years throughout the 1990s (Ryan et al. 2002). Concentrations have been doubling in marine mammals about every 5 years (Hites 2004) and in marine birds about every 5.7 years (Elliott et al. 2005).

With the withdrawal of pentaBDE and octaPBDE from the market in Europe and North America, a decrease in environmental concentrations would be expected, similar to the decrease seen in other POPs after controls were instituted. All PBDEs are currently being assessed under CEPA, but only decaBDE is still in use. It is distributed in commercial and consumer products to a greater extent than PCBs were, and there is evidence that it can break down into the more toxic penta- and octaBDE forms.

WHY IS IT HAPPENING?

With thousands of substances in use, it may be surprising that so few have emerged as environmental issues. Those that do, including the examples in this paper, share a similar history. At the outset, they were discovered, produced, and used freely as improvements to commerce and society, without regard for their transport or fate within the environment. Their potential hazard began to be recognized as residues accumulated in people and wildlife near the top of the food chain. Toxicological studies were followed a few years later by campaigns to reduce applications and, ultimately, by controls to restrict or eliminate manufacture, use, release, and disposal. Because there are often many possible sources for POPs and other contaminants, it is a challenge to make the links between the source and the effects to evaluate the success of mitigation efforts.

The Canadian Environmental Protection Act of 1988, and its subsequent amendment in 1999, were passed to prevent environmental pollution. Part of the intent of CEPA (1999) is to protect human health and the environment from substances in use. Despite regulations and voluntary controls, however, there are still sources of continuing, low input of contaminants to the provincial environment:

- Use of decaBDEs in furniture, textiles, plastics, and other consumer goods.
- Local, industrial, and other activities continue to produce small amounts of contaminants. Examples are burning salt-laden wood waste in boilers and trash in backyard burn barrels; both activities produce dioxins and furans (see "What You Can Do").
- Breakdown processes in soils and sediments that are still releasing contaminants from past uses (such as DDT).

- Accidental releases or spills of controlled pollutants. In the case of PCBs, there remains a risk that they may be released from controlled storage and landfill sites and from electrical equipment still in use.
- Transport over long distances in the atmosphere from parts of the world where they are still in use. Scientists suspect that the slow rate of decrease for DDE in wildlife, despite the long-time ban on the parent pesticide throughout North America, is due to long-range transport from other continents as well as the slow release of residues from past use.

WHY IS IT IMPORTANT?

All of the substances discussed in this paper are threats to human health and the environment. Human health risks have been monitored and controlled through regulatory protection of food, limits on exposure in the workplace, and limits on exposure from consumer and industrial products and other activities. Because the risks have been recognized retrospectively, however, they have been hard to manage for chemicals already released into the environment. For example, the fact that organochlorine pesticides caused eggshell thinning in birds was an unexpected impact, far removed from where the hazards might have been expected. More recently, harbour seals continue to show demonstrable physiological effects from POPs in their body tissue, and the cumulative effect of POPs in killer whales is a serious concern.

The costs of contamination, both to the economy and to the environment, have not been calculated. Economic costs range from loss of livelihood, loss of markets, and loss of harvest (e.g., closures of shellfish harvesting areas) to direct costs for cleaning up thousands of contaminated sites, replacing commercial and industrial equipment, and paying for monitoring services and regulatory systems.

WHAT IS BEING DONE ABOUT INDUSTRIAL CONTAMINANTS?

Internationally, Canada was the first country to ratify the Stockholm Convention on Persistent Organic Pollutants, in 2001. The objective of this international agreement is to protect human health and the environment from persistent organic pollutants. It calls for the elimination, immediately or in the long term, of some of the world's most dangerous chemicals: PCBs, dioxin and furans, hexachlorobenzene, and the pesticides DDT, dieldrin, aldrin, endrin, chlordane, heptachlor, toxaphene, and mirex.

In 2000, Canada established the Canada Persistent Organic Pollutants Fund with a commitment of $20 million to help developing countries and those with economies in transition deal with POPs. The fund is administered by UNEP and the World Bank and assists countries to implement the Stockholm Convention. As of mid-2005, about half the funds had been dispersed to over 70 projects.

In Canada, the Canadian Environmental Protection Act (CEPA), includes procedures for investigating and assessing substances, and for regulating substances that are, or might become, toxic as defined by CEPA. CEPA requires the Minister of the Environment and the Minister of Health to "categorize" all of the approximately 23,000 substances on the Domestic Substances List (DSL). This is a prioritization process to identify substances on the DSL that should be subject to screening assessments and potential control if they are found to be toxic. The program is intended to identify those substances with the greatest potential for exposure or that are persistent or bioaccumulative and inherently toxic to humans and other living organisms. All substances on the DSL are to be categorized by late 2006. This has led to the creation of two Priority Substances Lists, comprising a total of 69 substances or groups of substances. Under CEPA provisions, these 69 substances have been assessed to determine if they are toxic and whether there should be controls over production and release to the environment. A CEPA Environmental Registry provides information to the public and supports public participation in environmental decisions (*www.ec.gc.ca/CEPARegistry/*). The Registry provides access to toxic chemical assessments, inventories of substances and their toxicity, the industries they are associated with, and proposed management strategies and regulations.

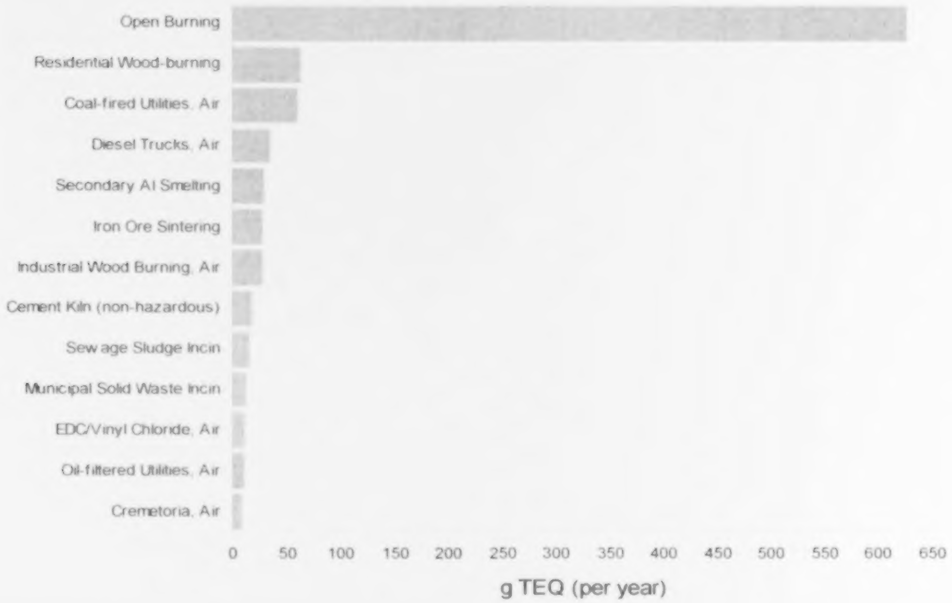
At the provincial level, an updated BC Environmental Management Act (2003) replaced two earlier pieces of provincial legislation, bringing provisions from both into one statute. New provisions for toxic substances and waste management were introduced, including changes affecting contaminated sites, hazardous wastes, and waste discharge regulations. New sediment criteria incorporated in the Contaminated Sites Regulation provide both a health measurement tool related to sediment concentrations for several of the substances mentioned in this paper and a strong inducement for industry to avoid creating future contaminated sites. The act covers a broad range of environmental regulations (see *www.qp.gov.bc.ca/statreg/stat/E/03053_00.htm*).

Under the Canada-wide Environmental Standards Sub-Agreement between federal and provincial Environment Ministers, coastal pulp and paper mills must reduce their atmospheric emission of dioxins and furans created by burning wood waste to less than 500 pg TEQ/m^3 by 2006 (CCME 2001). The atmospheric emissions are a byproduct of burning sawmill waste from logs transported in salt water booms. Because salt contains chlorine, when salt-laden wood is burned in pulp mill boilers, it creates small quantities of dioxins and furans. Currently, BC has eight coastal mills with boilers that must meet the criteria under this standard.

WHAT CAN YOU DO?

One source of POPs and other contaminants in the environment is under the control of the individual. The US Environmental Protection Agency (EPA) found that the largest source of dioxin and furan emissions in the US is now the uncontrolled burning of household trash (backyard burning). It found that burning the trash from as few as two average households releases as much dioxins and furans into the environment in a year as a modern full-scale municipal waste incinerator handling the garbage of 40,000–120,000 households (Lemieux et al. 2000). The EPA estimates of the total dioxin and furan load to the environment from backyard burning in the US are 10 times higher than the total emissions from the next highest sources—residential wood burning and coal-fired utilities (FNB and IOM 2003; see Figure 13). The health risk for people from this source may be exposure through food. Dioxins released into the air settle on plants, which are then eaten by meat and dairy animals. The animals store the dioxins in fatty tissue and people are exposed to the chemicals when they consume the meat and dairy products.

Figure 13. Dioxin emitted in 2004 to air by source in the US (g TEQ per year).



Source: US EPA and National Academy of Sciences.

Note: In Canada, other dioxin sources (e.g., slash burning and burning in beehive burners), may be relatively more important as dioxin sources than in the US.

This source of contaminants would be eliminated by halting the practice of burning waste in open piles or burn barrels. Because this is primarily an issue in rural areas where there is often less access to recycling or waste disposal services, there is an important role for regional districts and communities to provide accessible transfer stations and drop-off boxes, and to develop recycling programs for rural households.

Many municipalities ban open burning as part of local smoke control regulations. Where such burning is still permitted, however, individuals can help solve this problem:

- Buy recyclable and reusable products and avoid disposable items. Buy in bulk and avoid excess packaging.
- Have waste picked up by a licensed waste removal company or take it to a local landfill or transfer station.

- Separate recyclables and drop them off at a local recycling centre. For information on recycling or disposal options, call the BC Recycling Hotline at 1-800-667-4321.
- Compost yard and garden waste, food, and leaves. Rent a chipper or hire a service to chip brush and wood to make mulch.
- Never burn toxic materials (e.g., tires, plastics, construction and demolition waste, treated and painted wood, or rubber).

For more information on avoiding backyard burning, see *wlapwww.gov.bc.ca/air/particulates/bbsgiyea.html.*

This is only one area in which individual actions can affect the quality of the environment. For additional information on preventing pollution, see The Canadian Pollution Prevention Information Clearinghouse (CPPIC). This searchable database of references and links aims to share scientific information and give Canadians access to information on pollution prevention. The clearinghouse is supported by Environment Canada and offers more than 1500 resources for business, government, educators, and individuals. (*www.ec.gc.ca/cppic/en/index.cfm*)

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Ecosystem Protection

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Ecosystem Protection

BACKGROUND

Protected areas are parcels of land or water designated as protected for a variety of reasons: to protect wildlife and provide refuge for endangered species; to conserve biological diversity, including ecosystems and their functions; to provide representative examples of ecosystems or special features; to provide research areas or reference sites for environmental monitoring; and not least, to provide recreation, educational experiences, and enjoyment for people. Many different groups have a role in protecting areas of land and water: federal, provincial, and local governments, First Nations, non-government organizations, community groups, and private landowners, and other individuals.

In 1987, the World Commission on Environment and Development called on all nations to place 12% of their land into protected areas (WCED 1987). This minimum goal outlined in the Brundtland Report, was adopted by several jurisdictions, including British Columbia. In 1993, the BC government defined a protected areas strategy that aimed to protect 12% of its land base by the year 2000. By the end of 2001 it had surpassed the goal by dedicating 11.86 million ha, or about 12.5% of the land base, as protected areas (BCMWLAP 2002).

Protection of marine areas was not considered specifically in the 1993 protected areas strategy and no targets for protection were set, although broad aquatic objectives were included. Worldwide, the designation of marine protected areas has lagged behind the designation of terrestrial areas. The first protected marine habitat along Canada's Pacific coast was 654 ha that are part of Strathcona Provincial Park, which was established in 1911. Little additional marine area was protected until the 1980s and 1990s when 75% of the current marine areas under protection in British Columbia were established (Lunn and Canessa 2005).

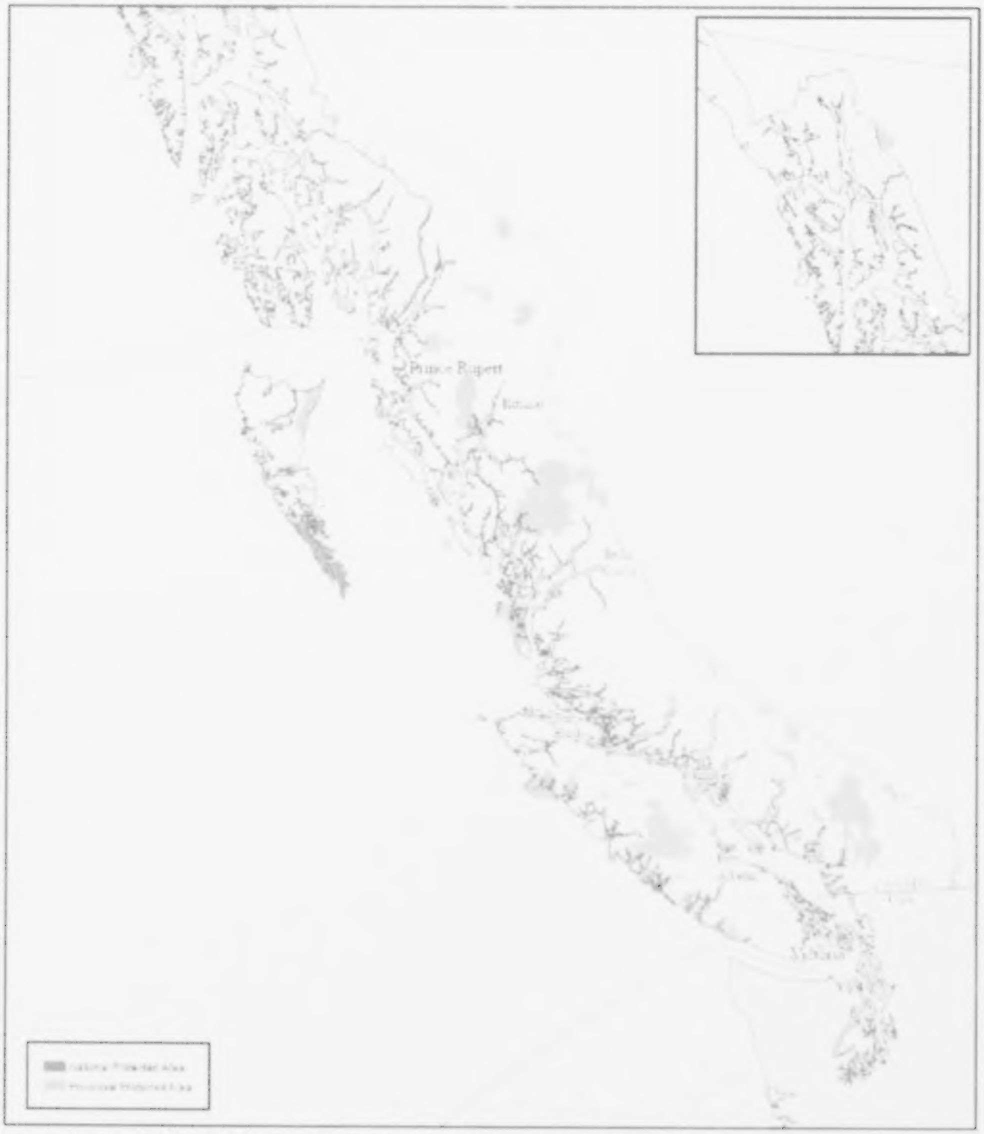
For this paper, the term "protected area" is used to describe areas of land or water that are legally protected in British Columbia through a variety of designations (Table 1). The designation an area receives defines the level of protection and depends on the objectives for the protected area and the agency creating it. For example, marine protected areas that are designated as migratory bird sanctuaries, national wildlife areas, or ecological reserves have management objectives that focus on conservation, research, and education, and place little or no emphasis on recreation and tourism. The level of protection is important for all protected areas, but particularly for marine protected areas, most of which are open to some level of recreational or commercial harvesting (e.g., Zacharias and Howes 1998; Jamieson and Levings 2001).

Table 1. Designations, legislative tools, and objectives of protected areas designated by provincial and federal agencies.

Managing agency Designation	Legislative tool	Objectives of the designation
Parks Canada		
National Marine Conservation Areas	National Marine Conservation Areas Act	To protect and conserve marine conservation areas of Canadian significance that represent the five Natural Marine Regions identified on Canada's Pacific coast. To encourage public understanding, appreciation, and enjoyment.
National Parks and National Park Reserves	National Parks Act	To maintain and/or restore the ecological integrity of natural environments. To encourage public understanding, appreciation, and enjoyment.
Fisheries and Oceans Canada		
Marine Protected Areas	Oceans Act	To protect and conserve: -fisheries resources, including marine mammals and their habitats; -endangered or threatened species and their habitats; -unique habitats; -areas of high biological diversity or productivity; -areas for scientific and research purposes.
Canadian Wildlife Service, Environment Canada		
Migratory Bird Sanctuaries	Migratory Birds Convention Act	To protect habitats that migratory birds use for breeding, feeding, migrating, and overwintering.
National Wildlife Areas; Marine Wildlife Areas	Canada Wildlife Act	To protect and conserve areas that are nationally or internationally significant for all wildlife but focusing on migratory birds.
BC Ministry of Environment		
Ecological Reserves	Ecological Reserve Act	To protect: -representative examples of BC's environment -rare, endangered, or sensitive species or habitats -unique, outstanding, or special features -areas for scientific research and education.
Provincial Parks	Park Act	To protect: -representative examples of terrestrial and marine diversity, and recreational and cultural heritage; -special natural, cultural heritage, and recreational features.
Protected Areas	Environment and Land Use Act	To protect: -representative examples of terrestrial and marine diversity, and recreational and cultural heritage; -special natural, cultural heritage, and recreational features.
Recreation Areas	Park Act (Park and Recreation Area Regulation)	To provide opportunities for public recreational use.
Wildlife Management Areas	Wildlife Act	To conserve and manage areas of importance to fish and wildlife. To protect endangered or threatened species and their habitats, whether resident or migratory, of regional, national, or global significance.

Sources: Governments of Canada and British Columbia 1998; Department of Justice Canada 2005; BC Ministry of Labour and Citizens' Services 2005.

Figure 1. Major national and provincial protected areas in coastal British Columbia. Not all protected areas used in the indicator analysis are shown.


Prince Rupert
Kitimat
Bella Coola
Victoria
▨ National Protected Area
▨ Provincial Protected Area

Source: Integrated Land Management Bureau, Ministry of Agriculture and Lands.

In this paper, only provincial and national protected areas, as designated in Table 1, have been included in the data analyses (mapped in Figure 1). Private protected areas and those created by local governments are not included but are currently only a very small portion of the overall protected area. In general, a protected area is defined as an area that has been reserved by law to protect all or part of the habitats and/or species it contains.

For this paper, marine protected areas (MPAs) are distinguished from terrestrial protected areas (TPAs). The term MPA is used in a generic sense for a protected area that includes intertidal or subtidal terrain, together with its overlying or contiguous water. Some MPAs will also include upland areas within their boundaries. A TPA does not include any subtidal or intertidal habitat. (Note that the Canadian and BC governments also have specific, legislated designations: "Protected Area" and "Marine Protected Area.")

NEW PROTECTED AREAS ON THE BC COAST

The Endeavour Hydrothermal Vents Marine Protected Area covers an area deep below the surface of the Pacific Ocean, 250 km southwest of Vancouver Island. Hot, mineral-rich water flows through cracks in the ocean floor, making a rare ecosystem. It is home to 60 species unique to the Juan de Fuca Ridge system, 12 of which do not exist anywhere else in the world. This MPA, designated in 2003, is the first under Canada's Oceans Act.
(See *www.pac.dfo-mpo.gc.ca/oceans/mpa/Endeavour_e.htm*)

The Gulf Island National Park Reserve was officially established in 2003. The Reserve consists of land on 16 islands, plus many small islets and reef areas in the southern Gulf Islands.

Why is it Important to Protect Ecosystems?

British Columbia's coastal and marine ecosystems provide critical habitat for thousands of plant and animal species, and provide many services on which humans rely. Some important reasons to protect ecosystems include:

- Maintenance of ecosystem services. Ecosystems provide services such as food production, water purification, waste treatment, oxygen production, climate regulation, flood protection, and erosion control, and many others (MEA 2005). These ecological services are critical for the survival of all organisms, including humans, and underpin human economic, social, and cultural systems. Even if it were possible to replace ecosystem services if they were no longer available, the cost would be astronomical. Costanza et al. (1997) estimated that, on average, Earth's ecosystems provide services worth US$33 trillion each year. Reid (2001) reported that every US$1 invested in watershed protection saves from $7.50 to $200 in costs for water treatment and filtration.

- Protection of biodiversity and specific natural features. In British Columbia, protected areas include habitat for rare and endangered species (e.g., rubbing beaches for killer whales), important genetic resources (e.g., colonies of reintroduced sea otters), and unique botanical or zoological phenomena (e.g., internationally significant seabird colonies) (BC Parks 1993). Although protected areas are essential, to conserve biodiversity there must be some level of protection for species and habitats in the larger matrix of habitats outside of protected areas (Wiersma et al. 2004).
- Contribution to human health and recreation. Intact ecosystems offer recreational, aesthetic, and cultural enjoyment (e.g., Kaplan, S. 1995; Kaplan, R. 2001). Viewing and interacting with nature is now regarded as having significant benefits for human well-being and health (Maller et al. 2002). Protected areas provide opportunities to connect with nature and appreciate scenic beauty. Nature education also plays an important role in the lives of many British Columbians. First Nations people place great cultural importance on species and ecosystems.
- Contribution to the economy. Protected areas attract millions of visitors each year: in 1999, 18.3 million recorded visits were made to BC's provincial parks (BC Parks 2005). These visits, together with park operations, resulted in expenditures of $533 million and 9100 person-years of employment. Conservation and protection programs also contribute to local economies by increasing opportunities to see wildlife and attract ecotourism. MPAs can also provide refuges that help sustain commercially valuable adjacent fisheries (Roberts et al. 2001; Gell and Roberts 2003).
- Preservation of wilderness. Preserving areas where human impacts are minimal allows species the best possible circumstances to live and to adapt to long-term changes such as global climate change. Undisturbed representative areas of major ecosystems are also critical for long-term research and monitoring (Haufler et al. 2002; Davis et al. 2003). Wilderness also has intrinsic value: ecosystems and organisms have value regardless of their role in human concerns (e.g., Takacs 1996).

Assessing the Effectiveness of Protection

In 2001, British Columbia and Alberta were the two provinces with the greatest proportion of land dedicated to protected areas (both with 12.5%). Other provinces and territories protected 3.2% to 12.1% of their areas. Nationally, in 2001, Canada had just over 7.3% of its land base in protected areas (BCMWLAP 2002).

These figures show the relatively high level of land protection in British Columbia relative to some other jurisdictions. However, the percentage of protected land required to maintain the province's ecosystems and biodiversity may be considerably more than 12% of the land base (Soule and Sanjayan 1998; Scudder 2002). Noss (1983) states that the amount of protected area required to adequately maintain any ecosystem will vary depending on the level of disturbance in the area surrounding the reserve. Thus, assessing whether we are protecting enough of our land base, in the right places, to capture a range of ecological values is only the first step in conserving ecosystems and biodiversity. Maintaining ecosystem processes and preventing species from going extinct requires attention to more than just the amount and location of protected areas (Noss 1995). The effectiveness of protection depends on the proximity to other protected areas, quality of the environment around the protected area, and the impact of internal and external stressors on the protected area.

The indicators and measures reported in this paper were developed to assess how effectively ecosystems in coastal British Columbia are protected.

INDICATORS

1. Key Indicator: Number, area, and size of protected areas on the BC coast

This is a status indicator. It addresses the question: How much area has been designated as protected? This indicator provides a measure of how much of the BC coast region is in protected areas.

Methodology and Data

Protected areas were considered coastal if they occurred within the Georgia Depression, Coast and Mountains, Southern Alaska Mountains, or Northeast Pacific ecoprovinces.

Protected areas in this indicator include provincial parks (Classes A, B, and C for terrestrial data; only Class A for marine data), ecological reserves, protected areas, recreation areas, Marine Protected Areas, national parks, and national marine conservation areas. Data also included those wildlife management areas, migratory bird sanctuaries, and national wildlife areas that contained marine (intertidal and subtidal) habitats. Protected areas are established and governed by federal (Environment Canada, Parks Canada, Fisheries and Oceans Canada) and provincial (Ministry of Environment) government agencies under a host of legislated acts (Table 1) Regional parks, wildlife reserves, private reserves, municipal parks, conservation lands leased to the provincial government, and areas subject to fisheries closures were not included in the analysis. Designations that do not provide protection under Canadian or BC legislation also were not included (e.g., UNESCO Biosphere Reserves).

Terrestrial data came from the Protected Areas System Overview (PASO), which is a web-based application administered by the BC Ministry of Environment. Marine data came from a variety of agencies and organizations (see Table 2).

A simple cross-tabulation of the proportion of protected areas in the coastal region (Table 3) was based on the number of protected areas derived from PASO and other sources in Table 2.

Table 2. Sources of data on protected areas used in this indicator.

Data	Source
Location and boundaries of protected areas	
Provincial parks, ecological reserves, protected areas, wildlife management areas, and recreation areas	Ministry of Agriculture and Lands, Victoria Service Centre (PASO database). Note: only wildlife management areas with marine components were used in analysis. Areas of these were taken from Orders in Council.
Endeavour Hydrothermal Vents Marine Protected Area	Endeavour Hydrothermal Vents Marine Protected Area Regulations: *http://laws.justice.gc.ca/en/o-2.4/sor-2003-87/154813.html*.
National wildlife areas and migratory bird sanctuaries	Environment Canada (Canadian Wildlife Service), Pacific Wildlife Research Centre, Delta, BC. *www.cws-scf.ec.gc.ca/habitat/*. Note: only those with marine components were used in analysis.
Gulf Islands National Park Reserve of Canada	Gulf Islands National Park Reserve, Sidney, BC.
Pacific Rim National Park Reserve of Canada	Pacific Rim National Park Reserve, Ucluelet, BC.
Gwaii Haanas National Park Reserve of Canada (land only)	Parks Canada, Queen Charlotte, BC.
Protected Areas System Overview	Ministry of Environment, Parks and Protected Areas Branch.
Descriptions of protected areas (e.g., area, year designated, management objectives)	
Provincial parks, ecological reserves, protected areas, wildlife management areas, and recreation areas	Ministry of Environment, also BC Parks: *wlapwww.gov.bc.ca/bcparks/*.
Gulf Islands National Park Reserve of Canada	Gulf Islands National Park Reserve, Coastal BC Field Unit, Sidney, BC. Additional information from Parks Canada: *www.pc.gc.ca/*.
Endeavour Hydrothermal Vents Marine Protected Area	Fisheries and Oceans Canada, Nanaimo, BC.
National wildlife areas and migratory bird sanctuaries	Canadian Wildlife Service, Delta, BC.
Pacific Rim National Park Reserve of Canada	Pacific Rim National Park Reserve, Ucluelet, BC. Additional information from Parks Canada: *www.pc.gc.ca/*.

For the rest of the analysis, protected areas were reorganized into protected units to take into account the geographic continuity of protected land and sea. For example, two protected areas that adjoin one another were considered to be one unit. Protected sea and protected land, however, were counted as separate units, even where they were adjacent and occurred within the same protected area. A protected area that occurred in four geographically distinct fragments was counted as four units. By organizing the data this way, the number of protected units is considerably larger than the number of protected areas because there are a large number of islands and islets (e.g., Gwaii Haanas National

Park Reserve has 1678 islets that are less than 1 ha at high tide). Each islet was considered to be an individual land unit, and these were often accompanied by separate, individual marine units. If a protected area extended beyond the boundaries defining the coastal region for this project (see Methodology), only the portion of the protected area within the boundary (Figure 1) was included.

Table 3. Extent and proportion of protected areas in terrestrial and marine environments in BC.

	Coastal BC[a]		All of BC
	Terrestrial	Marine[b]	Terrestrial
Extent of area protected (× 1000 ha)	2,409	240	11,580
Proportion of total protected area in BC	21%	2%	
Proportion of total area of BC	11.7%	0.5%[c]	12.5%

Sources: See Table 2.

[a] Coastal BC includes Georgia Basin, Coast and Mountains, and Southern Alaska Mountains ecoprovinces.

[b] Marine environments are defined as subtidal and intertidal areas.

[c] Total marine area of BC is defined as Pacific waters under Canadian jurisdiction (ca. 45 million ha).

Protected units were assigned to one of six size classes: less than 10 ha; 10–99 ha; 100–999 ha; 1,000–9,999 ha; 10,000–99,999 ha; and 100,000–406,000 ha (the largest contiguous protected area on the coast is 406,000 ha).

The datasets for terrestrial and marine units were analyzed separately. For each, the protected units data were integrated into a single Geographic Information System (GIS) layer. Terrestrial analysis included all area protected above the high tide line. Marine analysis included all protected subtidal areas (below the low-tide line) and intertidal areas (between the low- and high-tide lines). Some parks and reserves that protect marine habitats include both marine (subtidal and intertidal) and terrestrial (upland) components. In these cases, the upland components were included in the analysis as terrestrial protected units and the marine components were included in the marine analysis. The number of units and the total area in each size class is shown in Table 4.

Recent changes to the marine boundaries of individual protected areas were taken into account where possible. Exceptions were two marine ecological reserves, Anthony Island and Kerouard Islands, which were transferred from provincial to federal jurisdiction, but their new federal designation (part of the proposed Gwaii Haanas National Marine Conservation Area) was still pending at the time of this analysis. The proposed marine park of 346,734 ha at Gwaii Haanas also was not included because it has not yet been legislated. Note that Gwaii Haanas National Park Reserve protects terrestrial areas, and these were included in the terrestrial dataset. The area of the Great Bear Rainforest protected areas on the central and north coast, which was announced as this publication was going to press was also not included in the analysis for the indicators.

Table 4. Number of protected units and their area in each size category, in coastal British Columbia.

Size class (ha)	Total protected land	% of total protected land	Total protected marine	% of total protected marine
		Number of units		
<10	2,280	85	428	74
10–99	152	6	78	13
100–999	149	6	46	8
1,000–9,999	52	2	24	4
10,000–99,999	29	1	5	1
100,000–406,000	7	<1	0	0
Total no. units	2,669		581	
		Area		
<10	956	<1	49	<1
10–99	2,576	<1	1,633	<1
100–999	28,967	1.3	15,734	6.6
1,000–9,999	155,341	6.7	83,414	34.9
10,000–99,999	624,755	27.0	137,935	57.8
100,000–406,000	1,497,045	64.8	0	0
Total area	2,309,587		238,766	

Sources: See Table 2.

Note: Upper limit for size (406,000 ha) is based on the area of the largest contiguous protected area on the Coast.

While the spatial data used in this indicator were being analyzed, the total area of protected areas (subtidal, intertidal, and upland portions) as reported by managing agencies was found to differ slightly from the total area calculated from the boundaries. These discrepancies are likely related to how recently the datasets had been updated and to the spatial scale at which boundaries were mapped. Given the limitations of the current spatial data, the boundaries of wildlife management areas, national wildlife areas, and migratory bird sanctuaries, in particular, should be considered as draft. In the present analysis of area occupied by protected area units, the values supplied by agencies listed in Table 2 were used whenever possible because these are the official, legal sizes of the properties and most likely current; when these figures were not available, calculations of area were made in ArcGIS.

Interpretation

Number and Size of Protected Areas

In 2005, there were 444 exclusively terrestrial protected areas in coastal British Columbia, totalling 2,409,503 ha (Table 3). This was 11.7% of the coastal land base. The coast region covers approximately 21% of the province's total land, and has 40% of the province's terrestrial protected areas by number and about 20% by area. Although 42% (444 of a total 1024) of the province's individual protected areas occur west of the Coast Mountains in British Columbia, only 12% (130 of 1024) contain marine (subtidal or intertidal) habitats.

The 130 protected areas that included marine habitats account for 240,324 ha of marine habitat (intertidal and subtidal zones) on the BC coast. The total protected marine area came to less than one percent (0.5%) of the Pacific waters in Canadian jurisdiction. Five protected areas are exclusively marine; the rest include portions of land above the high-tide mark. Some scientists suggest that even this low extent of marine protection in British Columbia effectively may be many times smaller, because some BC marine protected areas allow activities such as dredging, bottom trawling, and commercial harvest (Jessen and Symington 1996).

The global national average for proportion of area protected is 5–6% (Soule and Sanjayan 1998), which is roughly half the proportion of BC's land mass that is currently protected. Although British Columbia protects more than the global average, the province's protected areas system is less comprehensive than those of some other countries, such as Venezuela, a world leader in protected areas. Venezuela is similar in size to BC but holds more than 19% of its land base in IUCN class I, II, and III protected areas (the classes most strictly managed for conservation and wilderness). Venezuela has also designated about 860,000 ha for marine protection versus BC's approximately 240,000 ha (WCPA 2005).

Some researchers suggest that conservation targets approaching 50% of the land base are needed to maintain biodiversity, even though these targets may be politically unpalatable (Soule and Sanjayan 1998). Studies of terrestrial ecosystems suggest that such large reserves are desirable for wilderness protection because they have been shown to be more effective at conserving a diverse array of species (e.g., MacArthur and Wilson 1967; Newmark 1987; Gurd et al. 2001). Target percentages have also been suggested in the marine area; for example, the World Parks Congress of 2003 called for strict protection or "no-take" areas in 20–30% of each type of marine and coastal habitat, which is almost 100 times more than the current extent of marine protection in British Columbia (WPC 2003).

Size Distribution of Protected Units

The protected areas in coastal British Columbia consist of just over 3000 geographically distinct units. Each unit corresponds to a continuous piece of either land or sea. This analysis shows that most protected units in coastal BC are less than 10 ha in size.

The predominance of small units of protected land is unavoidable given the high number of separate islands and islets found on the BC coast. Of the 2280 land units under 10 ha, 1678 of these (74%) are islets less than 1 ha in Gwaii Haanas National Park Reserve in the Queen Charlotte Islands. The next two size classes (10–100 ha and 100–1000 ha) contain a total of 12% of terrestrial units. Despite this, the small protected units contribute very little to the total area protected on the BC coast. Although only 3% (88) of terrestrial units are larger than 1000 ha, they account for 98% of the area of protected land (Table 4).

With respect to marine protection, the Dewdney and Glide Islands Ecological Reserve and the Moore / McKenny / Whitmore Islands Ecological Reserve, both on the east side of Hecate Strait, contribute substantially to the high number of small marine units because of the many islets. Although islets are counted as land, they may be spaced so that each has its own separate marine margin. These two ecological reserves together account for 54% (231) of the units under 10 ha. Although small land units are inevitable when protecting islets, the occurrence of small marine units is the result of how reserve boundaries are placed. Only 5% (29) of marine units exceed 1000 ha, but they account for more than 92% of the protected marine area. The five largest marine units (larger than 10,000 ha) make up more than half of the total marine area protected in British Columbia.

Coastal BC has seven protected land units larger than 100,000 ha (four of which contain marine habitats); together they account for more than 65% of coastal protected area. The remaining 35% of protected area on the land occurs in smaller areas. These smaller areas may capture key habitats for wide-ranging species, provided their small size is mitigated by good quality habitat in the surrounding matrix (Noss 1995).

Even large protected areas can be ineffective at conserving some large mammals on land and at sea (Noss 1995; Gerber et al. 2005). In the long term, viable populations of grizzly bears, cougars, wolves, and whales that live on BC's coast cannot be conserved by protected areas alone because collectively they require more space than any single protected area can provide (Grumbine 1990; McLellan and Hovey 2001; Killer Whale Recovery Team 2005). Ideally, a protected landscape should include a network of adjoining habitats in large core protected areas, along with functional corridors between protected areas, surrounded by buffer zones of sustainably managed areas and privately protected land (Woodley 1997; Noss et al. 1999). One recent Canadian study found that protected land areas of about 31,000 ha were large enough to conserve mammal species sensitive to disturbance if the landscape within 50 km of the boundaries contained at least 180,000 ha of effective habitat (Wiersma et al. 2004).

2. Key Indicator: Proportion of coastal terrestrial and marine ecosections that are protected

This is a status indicator. It addresses the question: How well are coastal ecosections represented by protected areas?

The Ecoregion Classification system, first used in 1988, describes areas of the province, including marine environments, that have similar climates, physical land and water features, vegetation, and wildlife potential (Demarchi 1996). This hierarchical system was designed to recognize ecosystems and ecological relationships on a small scale by identifying discrete units throughout the province. The classification has three lower levels: ecoprovinces, ecoregions, and ecosections. There are four ecoprovinces along BC's coast: Georgia Depression, Coast and Mountains, Southern Alaska Mountains, and Northeast Pacific. The coastal ecoprovinces are divided into 10 ecoregions (Appendix 1) and these are further divided into 40 ecosections (Appendix 2).

The Ecoregion Classification system was used in this indicator (and throughout this paper) because it is widely used in wildlife and habitat management in British Columbia.

Methodology and Data

The same definition and geographic location of protected areas was used in this indicator as in Indicator 1. Data sources are listed in Table 2.

For this analysis, GIS coverages of provincial ecosection boundaries were used to determine the location of individual protected areas in coastal BC (Appendix 2). Twenty-eight ecosections are entirely terrestrial. Twelve ecosections are marine: 2 exclusively so, and 10 meet the land and include islands and islets. For each of the 10 marine ecosections that include terrestrial areas, the marine and land portions of the ecosection were calculated separately. For example, the Juan de Fuca ecosection has a marine portion of 150,900 ha and a land portion of 73 ha. The protected marine area was calculated as a percentage of the marine portion of that ecosection, and the terrestrial protected area was calculated as a percentage of the land portion.

Data came from a variety of agencies and organizations (listed in Table 2). For each, the protected areas data were integrated into a single GIS layer. A data layer with the most recent ecosection boundaries was overlaid with the protected areas data to calculate the area protected within each ecosection.

Terrestrial and marine datasets were kept separate as far as possible. Some parks and reserves protect both marine and terrestrial components; in these cases, marine and upland components were separated for the analysis.

As in Indicator 1, recent changes to the boundaries of individual protected areas were taken into account where possible. Although Anthony Island and Kerouard Islands were transferred from provincial to federal jurisdiction, their new federal designation as part of the proposed Gwaii Haanas National Marine Conservation Area was still pending at the time of reporting; therefore the marine waters around Gwaii Haanas were not included in the marine dataset.

Combining data on the protected areas was difficult because data were mapped to different scales: some to the provincial 1:20,000 or 1:250,000 coastline, and some to the Canadian Hydrographic coastline (range of scales, 1:5,000 to 1:1,000,000). Ecosections were mapped to a 1:250,000 coastline. This made it hard to establish a common coastal baseline. To integrate the data from these sources, some transformations and spatial editing were necessary.

Because the coastline was based on different mapping sources, it could not be used to accurately calculate the extent to which upland and intertidal/subtidal components of protected areas occurred in either marine or terrestrial ecosections. In cases where management documents did not state the extent of intertidal and subtidal areas in a protected area, the spatial dataset was the only means of calculating these areas. Where possible, GIS calculations of area were compared with figures reported in management documents to resolve significant discrepancies.

Where an ecosection boundary bisected a protected area, the amount of protected land or ocean was calculated for each ecosection. If a protected area extended beyond the coastal boundaries set for this paper, only the portion of the protected area within the coast was included.

Table 5. Ecosections categorized by percentage of total area protected.

	Number of ecosections		
Percentage protected	Terrestrial	Marine	Terrestrial portions of marine[a]
0	0	1	0
<1	3	4	0
1–4.9	9	6	1
5–9.9	4	1	2
10–14.9	3	0	1
15–19.9	4	0	1
20–24.9	3	0	3
25–29.9	0	0	0
30–34.9	1	0	0
35–39.9	0	0	0
40–44.9	0	0	1
45–49.9	0	0	0
50–54.9	0	0	0
55–59.9	0	0	0
60–64.9	0	0	1
>65	1	0	0
Total	28	12	10

Sources: See Table 2.

[a] Terrestrial portions of the 10 marine ecosections that contain small amounts of land are shown in a separate column.

Table 6. Area and percentage of each ecosection that is protected.

	Terrestrial			Marine[a]		
Ecosection	Total area (ha)	Protected area (ha)	% of area protected	Total area (ha)	Protected area (ha)	% of area protected
Alsek Ranges	352,933	352,889	>99	–	–	–
Central Boundary Ranges	844,945	9,666	1	–	–	–
Central Pacific Ranges	2,069,387	42,713	2	–	–	–
Continental Slope	674	241	36	3,330,000	1,139	<1
Cranberry Upland	426,601	1,382	<1	–	–	–
Dixon Entrance	1,199	0.002	<1	1,081,000	663	<1
Eastern Pacific Ranges	1,353,208	239,029	18	–	–	–
Fraser Lowland	305,674	4,472	1	–	–	–
Georgia Lowland	123,881	10,794	9	–	–	–
Hecate Lowland	1,520,304	60,574	4	–	–	–
Hecate Strait	3,130	467	15	1,278,000	1,516	<1
Johnstone Strait	3,136	561	18	242,000	8,276	3
Juan de Fuca Strait	73	13	17	150,000	3,076	2
Kimsquit Mountains	763,089	171,596	22	–	–	–
Kitimat Ranges	2,255,611	469,923	21	–	–	–
Leeward Island Mountains	933,112	149,757	16	–	–	–
Meziadin Mountains	444,337	2,239	<1	–	–	–
Nahwitti Lowland	336,876	20,721	6	–	–	–
Nanaimo Lowland	298,919	4,148	1	–	–	–
Nass Basin	624,757	38,763	6	–	–	–
Nass Mountains	1,248,946	59,212	5	–	–	–
North Coast Fjords	9,958	245	2	930,000	25,001	3
Northern Boundary Ranges	567,274	63,471	11	–	–	–
Northern Island Mountains	577,428	52,618	9	–	–	–
Northern Pacific Ranges	982,626	9,344	1	–	–	–
Northwestern Cascade Ranges	44,156	4,570	10	–	–	–
Outer Fjordland	433,526	13,824	3	–	–	–
Queen Charlotte Lowland	327,272	68,648	21	–	–	–
Queen Charlotte Ranges	347,399	116,398	34	–	–	–
Queen Charlotte Sound	4,278	828	19	3,624,000	59,509	2
Queen Charlotte Strait	24,689	1,055	4	246,000	8,284	3

Table 6 continued.

	Terrestrial			Marine[a]		
Ecosection	Total area (ha)	Protected area (ha)	% of area protected	Total area (ha)	Protected area (ha)	% of area protected
Skidegate Plateau	330,365	36,441	11	–	–	–
Southern Boundary Ranges	719,278	15,242	2	–	–	–
Southern Gulf Islands	97,065	4,006	4	–	–	–
Southern Pacific Ranges	1,064,659	174,643	16	–	–	–
Strait of Georgia	73,536	5,238	7	819,000	30,300	4
Sub-Arctic Pacific	–	–	–	17,098,000	0	0
Transitional Pacific	–	–	–	14,850,000	9,689	<1
Vancouver Island Shelf	5,648	3,430	61	1,675,000	92,432	6
Windward Island Mountains	1,076,847	200,904	19	–	–	–

Sources: See Table 2.

[a] Marine area refers to intertidal or subtidal area.

Note: Ten marine ecosections contain small amounts of land; this has been separated and included in the Terrestrial category.

Interpretation

Ecosystems within British Columbia are not equally represented by the system of protected areas (Table 5). No marine ecosection has more than 6% of the area designated as protected and five marine ecosections have less than 1% of the area protected (Table 6). All terrestrial ecosections are represented, but 20 of the terrestrial ecosections have less than 10% of the area protected. Terrestrial representation ranges from 1% protected (seven ecosections) to more than 99% (the Alsek Ranges). The Alsek Ranges ecosection includes 352,933 ha within the Tatshenshini-Alsek Park. In its entirety, the Park covers nearly 1 million ha, but only the Alsek Ranges were considered coastal and were included in this analysis. Tatshenshini-Alsek Park and adjacent parks in the Yukon and Alaska together are the largest contiguous protected area in the world (approximately 8.5 million ha).

Critics of British Columbia's protected areas system are concerned that the more economically valuable ecosystems are under-represented (Soule and Sanjayan 1998) compared to mountaintops and wetlands. The best represented terrestrial ecosections (20–34% of the ecosection) are generally rugged and mountainous parts of the central coast: the Queen Charlotte Ranges, the Kitimat Ranges, and the Kimsquit Mountains. The northeastern part of the Queen Charlotte Islands, where muskegs and wetlands are extensive, is also well represented, with 21% of area protected. The three terrestrial ecosections that have less than 1% of their area protected are Cranberry Upland (east of the Nass Mountains), Meziadin Mountains, and the Northern Pacific Ranges.

Representation of the Strait of Georgia ecosections increased in 2003 with the addition of the Gulf Islands National Park Reserve, which extends approximately 200 m offshore. Protected areas in the Transitional Pacific ecosection increased with the addition of the Endeavour Hydrothermal Vents (DFO 2005). Marine ecosections, however, continue to be poorly represented. The Transitional Pacific ecosection still has less than 1% protected. Other marine ecosections with less than 1% of their area protected are Continental Slope, Dixon Entrance, and Hecate Strait. The Subarctic Pacific ecosection, which is the summer feeding ground for Pacific salmon (CPAWS 2005a), has no protected area. Overall, little or none of the western and northern marine ecosections of BC are currently protected.

Of the 12 primarily marine ecosections, the Vancouver Island Shelf is best represented with 92,430 ha (5.5%) of its 1.6 million ha protected (Table 6). Pacific Rim National Park Reserve is the largest protected area in this ecosection, with nearly 20,400 ha of marine habitats protected. This ecosection has nutrient-rich waters and is home to kelp beds, many species of shellfish and fish, seals, sea otters, grey whales, and transient killer whales.

The terrestrial portions of marine ecosections were, in all but two cases, 10,000 ha or smaller in total area. Therefore, the percentage of a terrestrial margin that is protected may appear large, but the total area protected is small. For example 61% of the terrestrial portion of the Vancouver Island Shelf ecosection is protected, but this amounts to only around 3430 ha. Altogether, about 12,000 ha of land is protected in primarily marine ecosections.

Supplementary Information: Protection of Marine Depth Zones

Protected marine areas differ from terrestrial ones because they also include a depth component. The depth of water plays a key role in characterizing marine ecosystems and their associated plants and animals. Ecosystems change from surface to deep water and from inshore to offshore environments; therefore, it is important when assessing the representation of protected marine ecosystems to consider how well different depths are represented.

The marine GIS data layers as described in the main indicator were used, along with bathymetric data obtained from the Land Information Management Bureau, to map protected areas according to six depth zones (see Table 7). The layers included the five zones used previously in the BC Marine Ecological Classification (Axys 2001), with the addition of the 1000–2000 m zone to distinguish the continental slope ecosystem.

Results for protected areas in the shallow zone (0–20 m) should be viewed cautiously because scale variations in the available data made it difficult to map the protected areas in nearshore zones accurately. Also, this analysis does not include level of protection, which is important when considering protected area coverage. Nonetheless, the results give a broad indication of the relative distribution of depth in protected areas.

The analysis shows that 90% of the protected marine area is less than 200 m deep, and about a third of the area (30%) is less than 20 m deep (Table 7). This is because most protected areas in the marine environment are adjacent to the shoreline (many also have an associated upland component). Nearshore protected areas play a vital role in protecting the interface between land and sea where there are important breeding and spawning habitats for fish and waterbirds, and key structural habitats like kelp and eelgrass beds.

Deep-water marine habitats and species are poorly represented in the current protected areas system, however, because there are only five protected areas in the sea away from land. The three protected areas with measurable offshore habitats are the Endeavour Hydrothermal Vents MPA, Checleset Bay Ecological Reserve (provincial) in the Vancouver Island Shelf ecosection, and Byers/Conroy/Harvey/Sinnett Islands Ecological Reserve (provincial) in the Queen Charlotte Sound ecosection. There are no protected areas in the continental slope zone, 1000 to 2000 m depth.

Table 7. Area of Pacific coast marine depth zones and proportion of each depth zone that is protected.

Zone	Depth range (m)	Total area (ha)	Protected area (ha)	% of total area protected
Shallow	0–20	740,000	73,108	10
Photic (where light penetrates)	20–50	1,520,000	68,240	4
Shallow continental shelf	50–200	6,010,000	77,610	1
Deeper continental shelf	200–1000	3,470,000	10,743	<1
Continental slope	1000–2000	2,580,000	0	0
Abyssal plain (deep sea)	>2000	31,060,000	9,689	<1
Total		45,380,000	239,390	<1

Source: Lunn and Cannessa 2005.

Note: Total protected area differs slightly from the total reported in Table 3 because of small variations in the geographic data available from different sources.

3. Secondary Indicator: Stressors in protected areas of coastal BC

This is a pressure indicator. It addresses the question: How effectively are ecological values being protected in coastal protected areas?

Despite being designated as protected, some protected areas may fail to meet their management objectives because of internal and external stressors (e.g., Alder 1996; Kelleher et al. 1995; Parks Canada 1998; PEICNP 2000). Internal stressors occur within the boundaries of a protected area and include roads, visitor services, recreational use, exotic species, and activities that consume or extract resources. External stressors occur outside the boundaries and include roads, urban development, forestry, mining, agriculture, fishing, pollution, and aquaculture. The effect that external activities have on protected areas varies according to the type of activity, its intensity, and how close it is to the protected area (Dearden 2001). For example, external pollution may migrate into a protected area. Protected areas downstream, or down-current in the marine environment, from agricultural, industrial, or urban areas are particularly vulnerable to waterborne pollution (e.g., Hillstrom and Hillstrom 2003). External stressors in the area surrounding a protected area can result in its isolation, effectively creating a protected island within a larger, inhospitable landscape.

This indicator identifies key stressors that may reduce the ability of the protected areas system to protect ecological values.

Methodology and Data

Between 2000 and 2002, BC Parks asked regional staff and other knowledgeable people to complete a Parks and Protected Areas Conservation Risk Assessment (CRA) survey to determine conservation values, risk factors, and stresses and threats to protected areas governed by provincial legislation. Relying on their professional judgement, local experience, and published literature, participants answered 21 questions. CRA forms were completed for 52% (232 of 444) of protected areas on the BC coast. This included 55% (71 of 130) of the protected areas that include a marine component.

Among the CRA survey questions, respondents were asked to identify internal and external stressors from a list (see Table 8) and to rank each one as having a low, medium, high, or unknown impact on the protected area. Responses from the survey were handled as follows:

- Only "high impact" stressors currently occurring in the protected areas were analyzed for this indicator; stressors deemed to be medium, low, or of unknown impact were not included in the analysis.
- Where a respondent for a single protected area divided the answer into multiple scores for the same stressor, each stressor was counted only once for that protected area at the highest impact rating received.

- Respondents occasionally appeared to include information in the wrong stress category, but these entries were not reclassified because of concern that the respondent's rationale might not be apparent. For example, although sport fishing was listed as an example of "gathering/harvesting activities" in the instructions, some respondents classed it as "recreation use."
- When a stressor was listed under the "other" category, the associated comments were used to assign it to another stress category where possible.

Table 8. The number and proportion of provincial protected areas surveyed that received scores of "high impact" for stressors listed in the Conservation Risk Assessment (CRA).

	Terrestrial protected areas		Marine protected areas	
	No.	%	No.	%
External stressors				
Forestry/mining/agriculture activity	32	20	29	40
Urbanization/tourism development	6	4	5	7
Access to protected area[a]	3	2	1	1
Internal stressors				
Recreation use[b]	30	19	20	28
Tourism/protected area facilities	20	12	13	18
Transportation and utility corridors	15	9	15	21
Exotic species	12	7	11	15
Gathering/harvesting activities[c]	10	6	22	31
Fire suppression	4	2	0	–
Loss of native species	2	1	0	–
Other stressors (internal or external)	7	4	0	–
Number of protected areas surveyed	161		72	

Source: Conservation Risk Assessment, Ministry of Environment, 2000–2002

Notes:

Marine protected areas include marine (intertidal and subtidal) habitat and may also include upland habitat. Terrestrial protected areas do not include marine habitat.

Percentage is based on the total number of protected areas assessed in the CRA study. Percentages do not add to 100% because a protected area may have 0 or >1 high-impact stressor.

[a] Access through protected area is included in "Transportation and utility corridors."

[b] Includes motorized activities (e.g., boats, ATVs, snowmachines) and non-motorized activities (e.g., vegetation trampling, firewood collection, berry picking, noise, anchor damage, feeding or harassment of wildlife).

[c] Includes recreational fishing, hunting, vehicle-kills of animals, and commercial mushroom harvesting.

Interpretation

The CRA survey relied on expert opinion rather than quantitative data, thus the quality of responses varied depending on the knowledge and experience of individual respondents and the information available for answering each question. Such information can be used only to give a broad indication of key stressors and the extent to which they occur in BC's protected areas.

Six of the 11 stress categories accounted for most of the "high impact" scores recorded for the protected areas. The most commonly recorded external stressor was forestry/ mining/ agricultural activity, which was listed for 20% (32) of the TPAs assessed and 40% (29) of the MPAs assessed (Table 8). Because the impacts of industrial activities can carry beyond their immediate location, management within a protected area may be negatively influenced by adjacent, incompatible activities (Ross et al. 2003).

Internally, 21% of all protected areas surveyed were experiencing pressure from recreational use; this is not surprising given the dense population in some areas of the coast. Parks and protected areas are popular destinations for people to visit and use for recreation. As tourism and visitation increases, more facilities and roads are built within and adjacent to protected areas. This reflects a fundamental conflict for protected area managers: between protecting wildlife and habitats and providing an enjoyable experience for people visiting the area.

Gathering/harvesting was also identified as the most common internal stressor in the marine protected areas. This highlights a difference between protected areas in terrestrial and marine environments. Provincial marine protected areas may not necessarily provide explicit protection of the water column or seabed (the seabed is under provincial jurisdiction only in "inland seas"). Such marine areas may be legally protected only when the federal government superimposes closures on the same area. Fisheries and Oceans Canada has regulatory authority for biological resources within MPAs designated by the province. As a result, the province plays only a small role in managing uses such as recreational fishing or harvesting activities. In terms of ecosystem conservation, fishing can disturb ecosystems and reduce population levels of target and sometimes non-target species (Jennings and Kaiser 1998).

Climate change was not listed as an external stressor in the CRA survey, but the effects may alter ecosystems (e.g., Parmesan and Yohe 2003; Root et al. 2003), species composition, and geographic ranges of species within and outside protected areas. In turn, this may alter the amount of a species' range that is protected by existing boundaries (Hannah et al. 2005).

Supplementary Information: Levels of Protection for MPAs

Nearly 85% of the marine area in BC's protected areas has been designated by the province, and the remaining 15% has been designated by three different federal agencies. Because different management agencies have different objectives, it can be difficult to determine how much protection an area really has. Even for two protected areas with the same designation, the permissible activities may differ according to site-specific objectives.

To assess the level of protection with respect to management objectives, an international standard classification system used by the World Conservation Union (IUCN) was used to rank BC's MPAs. The IUCN categories are meant to reflect management intent rather than the result of management effectiveness (IUCN 2004). Following a draft protocol developed by the Canadian Council on Ecological Areas, staff from federal and provincial ministries responsible for the protected areas placed each area in an IUCN management category. Most MPAs were assigned to one of six categories (described in Table 9), but 16 MPAs could not be assigned an IUCN category and were designated as "Other." The management objectives of these protected areas fell outside the IUCN's categories either because the site focused exclusively on tourism or because development had superseded conservation goals.

Table 9. Number and size of BC MPAs in each IUCN management category.

IUCN category	IUCN name	Primary management goal	No. of MPAs	Area of MPAs (ha)
Ia	Strict nature reserve	Science or wilderness protection	21	68,000
Ib	Wilderness area	Wilderness protection	7	1,468,200
II	National park	Ecosystem protection and recreation	66	551,700
III	Natural monument	Conservation of specific natural features	8	5,900
IV	Habitat/species management area	Conservation through management intervention	9	21,400
V	Protected landscape/seascape	Landscape/ seascape conservation and recreation	1	130
VI	Managed resource area	Sustainable use of natural resources	1	123,000
Other	Unclassifiable in IUCN system		16	4,000
Total			129	2,242,330

Note: The area of MPAs includes both marine (intertidal and subtidal) and upland portions of MPAs; Endeavour Hydrothermal Vents MPA was not included in this analysis.

Of the 129 MPAs assessed, half fell into IUCN Category II (national parks). Although the intent is to manage these areas for ecosystem protection and recreation, in reality very few are completely closed to harvest of marine organisms (Zacharias and Howes 1998). According to Jamieson and Levings (2001), Canada lacks "no-take" areas of sufficient scale to offer significant protection of functional marine ecosystems. Many of the smaller reserves provide recreational opportunities. However, most of the area protected, more than 1.5 million ha (70% of the area of provincial MPAs), is managed with the intent to protect wilderness, ecosystems, or natural features. Seven marine reserves account for 1,468,200 ha (94%) of the total area that is managed for conservation rather than recreation.

4. Key Indicator: Proportion of ecologically intact land within protected areas in coastal BC

This is an impact indicator. It addresses the questions: How much of coastal ecosystems is intact ("wilderness")? How much of the intact area is protected?

The presence of roads is a meaningful indicator for assessing the ecological integrity of terrestrial ecosystems. This is because roads open up areas to other types of human disturbances and have cumulative impacts that persist as long as the roadbed is in place (Noss 1995). In British Columbia, a lack of roads is indicative of ecological integrity because roads accompany most of the province's high-impact activities (i.e., industrial forestry, mining, agriculture, urbanization). In addition, roads affect natural ecosystems and wildlife by disturbing and destroying habitat, acting as barriers to wildlife movement, increasing mortality through roadkill and illegal harvest, altering water flow patterns, and increasing pollution and sedimentation (Crist et al. 2005). By fragmenting habitat and reducing the landscape connectivity necessary for movement and dispersal of animals and plants, roads also impede gene flow among populations and reduce the resilience of some species populations to disturbance (Simberloff et al. 1992). Roads may also provide avenues for invasion by alien species (e.g., Prasad 2000) and may affect animal behaviour. For example, grizzly bears may avoid portions of their habitat to avoid vehicle traffic (McLellan and Shackleton 1989; McLellan 1990).

This indicator shows how much of coastal BC is intact (roadless) and how much of this intact area is currently protected in provincial and national protected areas.

Methodology and Data

Intact areas were defined as areas of at least 2000 ha that are more than 5 km away from roads. Because no definitive effective size has been set for a protected area, the 2000-ha minimum size was chosen on the theory that larger reserves are more effective in conserving biodiversity (MacArthur and Wilson 1967; Newmark 1987; Gurd et al. 2001). The 2000 ha (20 km^2) figure used here is a conservative minimum size given the demands of some large vertebrate species for space. For example, bears may have home ranges of 20 to 1500 km^2 (Banci 1991).

The minimum 5 km distance from a road follows the methodology used in a similar analysis of roadlessness (Lee et al. 2003) that set a minimum polygon width of 10 km. That effectively ensured that "roadless areas" were defined as being a minimum of 5 km from the nearest road. The intent was to incorporate the influence of roads encroaching on protected areas in the analysis (in addition to the roads within protected areas). The size and number of areas defined as intact was determined using provincial GIS data that incorporated data layers for roads from the 1:20,000 TRIM II (Terrain Resource Information Management) transportation layer, coastal ecoprovinces, and provincial and national protected areas (Table 2).

The road data included paved and dirt roads, railways, and runways that are currently used by vehicle traffic, as well as seismic lines. A recent analysis of satellite images by the Ministry of Agriculture and Lands found that the TRIM II database does not capture all current roads: about 6% of roads in the Georgia Depression and about 15% of roads in the Coast and Mountain ecoprovinces are not captured in TRIM II (unpubl. data). These appear to be largely private forestry roads. In addition, the following were not included in the analysis: ferry routes, overgrown roads, cart and tractor tracks, winter tracks and trails, footpaths, portage trails, ski and bike trails, equestrian and pedestrian hiking trails, and any proposed trails and roads. Thus, this indicator shows a conservative estimate of the presence of roads in BC.

Protected areas were considered coastal if they occur within the Georgia Depression or Coast and Mountains ecoprovinces (Appendix 1). The Southern Alaska Mountains ecoprovince was not included in this analysis. Protected areas in this indicator include provincial parks (Classes A, B, and C for terrestrial data; only Class A for marine data), ecological reserves, protected areas, recreation areas, and national park reserves. Not included in the analysis were community watersheds, private reserves, regional parks, wildlife reserves, wildlife management areas, and areas subject to fisheries closures. Designations that do not provide protection under Canadian or BC legislation also were not included (e.g., UNESCO Biosphere Reserves).

The "intact areas" layer was created by removing a buffer zone of 5 km on each side of all roads shown in TRIM II. The resulting polygons were retained if they were 2000 ha or larger. If two small polygons were adjacent and together were more than 2000 ha, they were included in the analysis. If a small polygon was adjacent to a polygon in another ecoprovince and together the area exceeded 2000 ha, the small polygon was included in the analysis. The ecoprovince and intact data layers were combined to create a map of the intact areas in coastal ecoprovinces. This information was then combined with the protected areas data layer to determine the amount of intact land within protected areas (Figure 2). Marine portions of each ecoprovince were not included (for a separate analysis of marine intact areas, see Indicator 5).

Figure 2. Intact ecosystems and protected areas in coastal and marine British Columbia. Intact ecosystems are based on the absence of human use, including roadways in terrestrial ecosystems (Indicator 4), and coastal infrastructure, fishing, and industrial activities in marine ecosystems (Indicator 5). Marine analysis is preliminary.

Prince Rupert
Bella Coola
Port Hardy
Intact Marine Area
Intact Terrestrial Area
▨ Protected Area

Source: For terrestrial areas, see the Integrated Land Management Bureau, Ministry of Agriculture and Lands data sources listed for Table 10. For marine areas, see data sources listed in Table 11.

Interpretation

The two ecoprovinces included in this analysis had similar proportions of their total land area in protected areas (10.2% for Coast and Mountains and 9.8% for Georgia Depression (Table 10). The two ecoprovinces differed in the proportion of land that is ecologically intact or roadless. The Coast and Mountains ecoprovince has 45.9% of its land area intact according to the definition used in this indicator; 6.8% of the ecoprovince land area is both intact and protected. In contrast, the Georgia Depression ecoprovince has only 2.8% of its land intact, with almost all of that (2.7%) in protected areas.

Table 10. Ecologically intact areas (more than 5 km from a road and larger than 2000 ha) and protected land areas in coastal ecoprovinces and all of BC.

	Total land area (ha)	Total area of intact land (ha)	% intact	Protected area (ha)	Intact protected area (ha)	% of protected area intact	% of coastal land protected and intact
Coast and Mountains ecoprovince	18,430,793	8,468,508	45.9	1,916,839	1,252,843	65.3	6.8
Georgia Depression ecoprovince	1,834,959	52,262	2.8	180,790	50,360	27.9	2.7
Provincial total	94,421,891	29,936,282	31.7	11,496,821	6,932,335	60.3	7.3

Sources: Integrated Land Management Bureau, Ministry of Agriculture and Lands:

- GeoData BC 1:20,000 TRIM II Transportation themes (*Arcwhse\gdbc\trimii\<tile>\ttrn*);
- Ecoregion Ecosystem Classification Units theme (*Arcwhse\wld\qes_bc\region.ecoprov*);
- Protected area coverage: Protected Areas System Overview (PASO), provincial (*Arcwhse/prk/tpas_bc/region.pa_name*) and federal (*Arcwhse/prk/qnpa_bc*).

This analysis, not surprisingly, shows the proportion of ecologically intact areas in BC increasing as latitude increases. The Coast and Mountains ecoprovince, which stretches from the highly developed southern edge of the province to the far north, is wilder (measured by intactness) than average for British Columbia. It appears that the northern parts of the ecoprovince have the most ecological integrity and that protected polygons are well embedded in a network of intact areas with good landscape connectivity.

Most of the intact parts of the Georgia Depression are already within protected areas, and almost all of the land surrounding these areas has roads. Therefore, each protected polygon (which could include more than one protected area if their boundaries adjoin) is isolated from other intact areas. Such a lack of connectivity between intact areas may leave the plants and animals that occur there more vulnerable to extinction and to problems arising from genetic isolation. It also reduces the ability of a species to move to more favourable habitat in response to climate change or other pressures.

5. Secondary Indicator: Proportion of ecologically intact marine habitat within protected areas along the BC coast

This is a status indicator. It addresses the questions: How much of the ocean is used by humans? How much can be considered intact or in a natural state?

People use the ocean for diverse purposes, many of which directly affect marine organisms and their habitat. This indicator pilots a similar approach to that used for the terrestrial land base in the previous indicator with the aim of identifying areas of the ocean that could be considered ecologically intact. Intact marine areas would have little or no evidence of human intrusion, so that natural processes can take place unaffected by human intervention (Kelleher and Kenchington 1992). In this indicator, the absence of selected human activities is used as a proxy for ecological intactness, and provides a coarse measure of the degree of human presence in the marine ecosystem. The actual environmental consequences of human activities depend on both the sensitivity of the locations and the intensity of the activities.

Methodology and Data

In the terrestrial environment, the presence of roads was used as a proxy for human activity, but there was no such proxy for the marine environment. Instead, all activities and uses likely to affect the marine environment, for which data were available, were mapped. Because data are not available for every activity, the marine uses that were mapped should be considered a conservative estimate. For example, human impacts that are ubiquitous in the ocean, such as chemical contaminants in the water, were not included in the analysis.

Data were downloaded from various government websites and ftp sites (Table 11).

To simulate the effects of activities that extend outward beyond their immediate location, a buffer area was included around locations. In the absence of information on the extent of the impact of such marine activities, all point and line data were buffered by 1 km. For ocean dumping and waterfront industrial activities, which were likely to have a more significant impact, a 5-km buffer was applied, as for the roads analysis in the previous indicator. Polygonal data for fishing areas were used without applying a buffer.

For extractive uses, the bottom trawling areas for 1996–2005, as documented in logbooks, summarized in 10-km grid cells, was obtained from Fisheries and Oceans Canada. Each cell showed trawling activity when three or more distinct vessels trawled in that cell. This means that areas that did not show trawling activities may have been trawled by one or two vessels. At the same time, it cannot be inferred that all ground within the trawled cells has been trawled. A more accurate determination could be made from commercial logbooks for fishing areas, but they were not available for this analysis.

Table 11. Sources of data used in analysis of human activities in marine areas, and the buffer distances for impacts used in the analysis.

Type of data	Source of data	Buffer distance[a]
BC coastline, marine ecoregions	Province of BC	None
Provincial protected area designations	Province of BC (*ftp://ftp.gis.luco.gov.bc.ca/pub/*)	None
National parks	Natural Resources Canada (*http://geogratis.cgdi.gc.ca/clf/en*).	None
Marine Protected Areas	Fisheries and Oceans Canada (*www.pac.dfo-mpo.gc.ca/oceans/mpa/Info_e.htm*).	None
Finfish and shellfish aquaculture	Province of BC (*ftp://ftp.gis.luco.gov.bc.ca/pub/coastal/*).	1 km
Bottom trawling	Fisheries and Oceans Canada (DFO) 1996 to 2005 groundfish trawl data (# of sets; no data if less than 3 distinct vessels fished in a grid) in 10 × 10 km grid.	None
Other commercial fisheries, recreational fisheries	Province of BC (*ftp://ftp.gis.luco.gov.bc.ca/pub/coastal/*) -Commercial urchin, shrimp, sea cucumber, scallop, salmon troll, salmon net, prawn, octopus, herring, herring roe, goose barnacle, geoduck, crab, and anchovy fishing areas. -Recreational squid, scallop, prawn, groundfish, crab fishing areas.	None
Offshore seismic lines, Offshore oil and gas test drill sites, Cruise ship routes	Oil and gas commission website (*www.offshoreoilandgas.gov.bc.ca/offshore-map-gallery/download.htm*).	1 km
Anchorages, boat launches, marine disposal sites, industry, moorage	Province of BC (*ftp://ftp.gis.luco.gov.bc.ca/pub/coastal/*).	1 km
Ammunition dump, built-up area, cable, ferry dock, marina, dump, ferry route, fish hatchery, lighthouse, mine tailings pond, underground mine, open pit mine, pier, raw materials pile (industrial waste), pit, quarry, settling basin, sewage leaching field, tailing pile	TRIM (Terrain Resource Information Management) – Province of BC.	1 km

Note: Extractive activities on land (e.g., mines) were limited to those occurring within 1 km of shore.

[a] Buffer distance represents the zone of impact around features that were considered to have impacts that extended beyond the point of action.

All datasets of marine activity or use were combined into a single GIS coverage. This was then overlaid on the marine area of each ecoregion (Appendix 1) to create a marine use layer for each ecoregion. The difference in area between the total marine area of each ecoregion and the marine use area was used to generate an "ecologically intact" layer for each marine ecoregion (Figure 2). The areas of all "intact" marine polygons in each ecoregion were calculated and all polygons with an area of 2000 ha or larger were selected and totalled (see Table 12). Because there is no agreement about how small marine areas can be and still be ecologically intact, the 2000 ha minimum size was chosen as a threshold to be comparable to the terrestrial analysis.

The same process described above was used to calculate the area of provincial and national parks, Marine Protected Areas, and their overlap with areas identified as ecologically intact. For further details of analysis, see Ban and Alder (2005).

Table 12. Ecologically intact and protected marine areas in marine ecoregions of British Columbia. Ecologically intact areas are defined by the absence of activities in Table 11 and a size >2000 ha.

Marine ecoregions	Total marine area (ha)	Total area of intact marine (ha)	% intact	Protected area (ha)[a]	Intact protected area	% of protect area intact	% of marine area protected and intact
Inner Pacific Shelf	1,414,336	337,612	23.8	57,586	16,277	28.3	1.2
Outer Pacific Shelf	11,014,389	1,419,566	12.9	167,000[b]	63,901	38.3	0.6
Transitional Pacific	14,850,500	14,516,127	97.7	93,812[c]	93,812	100	0.6
Subarctic Pacific	17,097,900	16,001,376	93.6	0	0	0	0
Georgia Basin	966,657	199,778	20.7	13,048	1066	8.2	0
Provincial total	45,343,782	32,474,459	71.6	331,446	175,056	52.8	0.4

Source: Ban and Alder 2005.

[a] Protected area designations used: national parks, provincial parks, ecological reserves, protected areas, marine parks.

[b] If the proposed Gwaii Haanas National Marine Conservation Area is included, the coverage by protected areas in the Outer Pacific Shelf increases by approx. 352,460 ha.

[c] Endeavor Hydrothermal Vents.

Interpretation

This was a preliminary attempt to map a selection of human activities in BC's marine environment, using available data and expert judgements for appropriate buffer distances. Although it is a conservative attempt (not all human activities in the marine area were mapped), it does show the extent of human activity on BC's continental shelf, and that only a small fraction of the ecologically intact marine area is protected.

The analysis shows that the continental shelf of British Columbia (Georgia Basin, Inner Pacific Shelf, and Outer Pacific Shelf ecoregions) is used extensively by humans, with less than 25% of any shelf ecoregion classifiable as ecologically intact (Table 12). Of the very small proportion of BC's marine area that is protected, only one-third would be considered ecologically intact, according to the definition used in this analysis. The proportion of marine area that is both protected and intact is 0.4%.

Human activities in the ocean do not have equal impact on the marine environment; but, because this analysis sought to identify areas of the ocean that are not affected at all, activities were not weighed by severity of impact.

Supplementary Information: Areas of BC coastal habitat purchased by the Pacific Estuary Conservation Program

Private landowners and individuals can play an important role in protecting ecosystems. They contribute through volunteer activities, by placing protective covenants on private land, and by donating money so that lands can be secured by land conservancies. These activities enhance and complement efforts by governments to protect ecosystems (Dempsey et al. 2002). This is a growing area of activity; in 2003 there were four major land trusts and an estimated 25 smaller, local land trusts in British Columbia (Scull 2003). The trusts rely on donations, bequests, and volunteers to operate their programs.

Although only 6% of BC's land base is privately held, a disproportionate amount of private land is valley bottoms, shorelines, estuaries, and other ecologically important landscapes. Acquiring land, often in populated areas, for conservation helps to secure critical wildlife habitat and to preserve biodiversity. This is particularly important because some species at risk in BC, such as the red-listed Townsend's mole (*Scapanus townsendii*), occur largely on private lands.

The Pacific Estuary Conservation Program (PECP) began in 1987 as a coalition of land trusts and government agencies intent on conserving important estuaries along BC's Pacific coast. It is currently a partnership between Ducks Unlimited Canada, Nature Conservancy of Canada, The Nature Trust of BC, The Land Conservancy of BC, BC Habitat Conservation Trust Fund, BC Ministry of Environment, Fisheries and Oceans Canada, and Environment Canada (Canadian Wildlife Service).

The PECP works with land owners to conserve shoreline and intertidal habitats. In the 17-year period from 1987 to 2004, the PECP bought 2636 hectares of estuary land and spent nearly $31 million on these land acquisitions (Table 13). The number of hectares available for purchase depends on opportunity (lands that come up for sale) and whether funds are available for the purchase. Funds not spent in one year may be carried over to the next to enable occasional large purchases. The single largest acquisition was of 567 ha in Widgeon Valley / Pitt River in 1991. The PECP has also facilitated the conservation designation of 46,000 hectares of adjacent intertidal Crown land through partnerships with the provincial government.

Table 13. Pacific Estuary Conservation Program land purchases, 1987–2004.

Year	Dollars spent	Hectares bought	Cumulative dollars	Cumulative hectares
1987	571,051	142	571,051	142
1988	322,870	108	893,921	250
1989	51,000	7	944,921	257
1990	4,114,207	259	5,059,128	516
1991	1,285,000	567	6,344,128	1083
1992	2,810,000	82	9,154,128	1164
1993	1,212,000	41	10,366,128	1205
1994	1,850,000	58	12,216,128	1263
1995	200,000	22	12,416,128	1286
1996	588,000	88	13,004,128	1374
1997	1,562,000	43	14,566,128	1417
1998	1,727,280	78	16,293,408	1495
1999	1,533,159	220	17,826,567	1715
2000	4,383,437	282	22,210,004	1997
2001	439,585	98	22,649,589	2095
2002	393,225	46	23,042,814	2141
2003	7,185,678	334	30,228,492	2475
2004	556,850	161	30,785,342	2636
Total	$30,785,342	2,636		

Source: Pacific Estuary Conservation Program Steering Committee 2005.

Land acquisition is only one way to protect specific habitats. The PECP also promotes voluntary stewardship by encouraging land owners to place conservation covenants on their land to protect ecological values. Conservation covenants are legal agreements that specify the ways in which the land can be used. Because they are incorporated into the land deed, conservation covenants protect the land in perpetuity (Dempsey et al. 2002).

HOW EFFECTIVE IS ECOSYSTEM PROTECTION IN COASTAL BC.?

Protected areas are a major component of British Columbia's commitment to protecting and restoring the quality and integrity of its environment. In 1993, the province's first priority for protected areas was to protect their ecological viability and integrity (Province of BC 1993). Up to January 2006, a total of 12.5% of BC's land base had been protected by national and provincial legislation, about double the area that was protected 15 years ago. Included in the province's strategy for protecting areas was the concept that the protected areas system should represent a balance of ecosystems and special features, although no locations or sizes for protected areas were specified.

Currently, terrestrial ecosystems are better represented than marine ecosystems. Along the coast, 11.7% of land is protected in 444 terrestrial protected areas that occupy 2.4 million hectares; in contrast, 130 protected areas, encompassing 240,000 hectares of marine habitat, protect less than 0.5% of Canada's Pacific Ocean jurisdiction. Despite this low proportion, nearly five times more marine area is protected on the coast of BC today than in the 1970s. Although designating marine areas for protection has lagged behind designating terrestrial areas at both global and regional levels, the upward trend in MPA establishment on the Pacific coast is consistent with a global increase in marine protected area.

The deep sea is one of the least represented areas, containing about 10,000 ha of protected area out of a total area of approximately 30 million ha. Generally speaking, the best marine protection is found in the zone less than 20 m deep; this is fortunate because the impact of human activity is probably also greatest near the shore. Ecosection representation is also relatively high in the highly populated ecosections along BC's south coast (e.g., Strait of Georgia, 4%; Leeward Island Mountains, 16%; Southern Pacific Ranges, 16%). In these disturbed ecosections, protected areas may act as islands of habitat, providing a basis for conservation where opportunities for further habitat acquisition are limited.

Only recently have activities outside the boundaries been given consideration in protected area management (Woodley 1997). The impacts of industrial activities are clearly extending into British Columbia's protected areas. Respondents to the Conservation Risk Assessment surveys considered that more than one-quarter of coastal protected areas were subject to "high" impacts from forestry, mining, and agriculture (including aquaculture) activities taking place outside of the protected area. Because the external origin of such impacts renders them beyond the immediate control of park management, cooperation and collaboration between different stakeholders within the larger ecosystem can be essential to meeting long-term conservation objectives (Ross et al. 2003).

A critical issue for protected areas is maintaining connections within the landscape to other intact or undisturbed habitats and other populations (PEICNP 2000). The predominance of protected areas less than 10 ha in size along the coast suggests that many exist in isolation, but the natural topography of coastal islands and islets makes small parcels of land unavoidable. Protected areas in the sea are not subject to the same limits on physical size, and yet most protected marine units are also smaller than 10 ha. Through the medium of water, marine areas are not necessarily isolated in the same way as terrestrial areas, but they may still suffer from lack of connections to other protected areas. To protect bottom-dwelling marine species, this problem might be overcome by designating marine corridors (Carr et al. 2003).

Connectivity between protected areas appears to be threatened by large amounts of activity and infrastructure in the intervening matrix between the province's protected areas. Roads are encroaching on the land, particularly in the Georgia Depression where only a quarter of the protected areas do not contain roads or have them within 5 km of their boundaries. A preliminary analysis of Canada's Pacific waters suggests that only a small proportion of the continental shelf remains undisturbed by human activity. It will be important to maintain and possibly restore connectivity in these disturbed environments if the protected areas within them are to maintain biodiversity and ecosystem function.

This analysis provides some measures of the extent, coverage, size, level of protection, and connectivity between protected areas in coastal BC. Although BC has a larger proportion of protected area than some jurisdictions, there is no scientific basis to suggest that 12.5% of the land and 0.5% of the marine environment will be enough to maintain the province's ecosystems and biodiversity in perpetuity (e.g., Soule and Sanjayan 1998; Wiersma and Nudds 2003; WPC 2003). If the protected areas system alone is insufficient for ecosystem conservation, wise management suggests that it is important to maintain some high-quality habitat in the spaces between protected areas (Noss 1995; Halvorson 1996; PEICNP 2000). This may be challenging in the Georgia Depression and along the continental marine shelf, where human activity appears to be closing in on existing protected areas, reducing the linkages between them. Partnerships to acquire property adjacent to protected areas and to conserve areas that link protected areas into larger ecological corridors may now be more important than ever. In addition to land securement, there is also a need for private land stewardship with land owners in the working landscape (e.g., forestry, agriculture).

WHAT IS BEING DONE TO PROTECT ECOSYSTEMS?

Putting conservation initiatives into action is rarely as easy as setting aside a piece of land or water and designating it as protected. All protected areas require at least a basic level of management. As well, protected areas exist within a landscape that may include development pressures in the area and local stakeholder concerns. Limiting the extent and type of activity that occurs outside protected area boundaries can affect local communities by decreasing those external stressors that limit conservation values within protected areas. However, limiting some industries may also increase the value of a local protected area in terms of ecotourism, tourist services, and ecological services. Decisions about where and what to protect can involve trade-offs between environmental and economic benefits and costs. For example BC's protected areas are enjoyed by millions of visitors every year, yet accommodating them often means losing or compromising some habitat to build roads, visitor centres, parking lots, trails, and other facilities. The need for staff and resources to manage visitors and facilities can conflict with the need for resources for conservation, monitoring and research.

Demonstrating their shared interest in the development of a marine protected area framework, the federal and provincial governments signed a Memorandum of Understanding Respecting the Implementation of Canada's Oceans Strategy on the Pacific Coast of Canada in September 2004. This agreement formalizes the commitment of both governments to achieve the objectives in Canada's Oceans Strategy and improve the governance of existing MPAs by creating a more integrated approach between jurisdictions (DFO 2002). Sub-agreements on MPAs, monitoring, and reporting of environmental indicators are currently being developed.

Protected areas are identified in the ongoing provincial Land and Resource Management Planning (LRMP) process. Several areas in the Central Coast LRMP and North Coast LRMP areas have been assessed for new protected status (see text box). Federal designations under consideration at time of writing include the Scott Islands Marine Wildlife Area; the Bowie Seamount, Race Rocks, and Gabriola Passage MPAs; and the Gwaii Haanas National Park Reserve and the Southern Strait of Georgia National Marine Conservation Areas.

BCs NEWEST PROTECTED AREA: THE GREAT BEAR RAINFOREST

On 7 February 2006, the government of British Columbia announced that a 1.2 million hectare protected area will be created in the central and north coast. The new area is along 400 km of the coast, from the northern extent of Vancouver Island to the Alaskan border. With the 600,000 hectares already protected in the region, this announcement will create a network encompassing 1.8 million hectares. Strict new controls on forestry and other activities will also protect against exploitation of an additional four million hectares in the same region.

Other protected area initiatives are under way by the federal government. Fisheries and Oceans Canada has been implementing rockfish conservation areas. These areas currently cover less than 1% of British Columbia's ocean (see Table 3). Since the passage of the Oceans Act, Fisheries and Oceans Canada continues to work on the establishment of Marine Protected Areas. The marine area under protection will more than double when the proposed Gwaii Haanas National Marine Conservation Area Reserve achieves official status. The proposal includes an area of Hecate Strait and Queen Charlotte Shelf of about 340,000 ha (Parks Canada 2003). The reserve would extend roughly 10 km offshore from the existing Gwaii Haanas National Park Reserve and Haida Heritage Site.

Conservation initiatives by the provincial and federal governments are complemented and enhanced by non-governmental organizations that play a significant role in ecosystem protection:

- The BC Trust for Public Lands was established in 2004 to secure and manage ecologically sensitive lands and to plan for biodiversity conservation across the province. The Trust is delivered through the BC Conservation Lands Forum, a partnership between government and the conservation sector. The minimum requirement for non-provincial government matching dollars will result in a $32 million conservation investment in the province ($8 million from the province) over five years. See the provincial government news release at (*www2.news.gov.bc.ca/nrm_news_releases/2004SRM0036-000815.htm*).

- Nature Canada and Bird Studies Canada work as Canadian partners with BirdLife International to designate Important Bird Areas (IBA) to protect and monitor a network of vital habitats for conserving bird populations and biodiversity around the world. Seventy sites have so far met the criteria for Important Bird Areas in BC: 36 islands with seabird colonies, 23 wetland and inland sites, 7 marine sites, 2 heron rookeries, and 2 shorebird migration sites. One tiny island has 55% of the world's population of Cassin's auklets—nearly two million birds. (*www.naturalists.bc.ca/projects/iba/iba_intro.htm*)
- The Habitat Conservation Trust Fund (HCTF) collects funds from surcharges on hunting, angling, trapping, and guiding licences. The funds are spent on projects that acquire, protect, restore, or enhance fish and wildlife habitat. In 2005, the HCTF funded fish and wildlife conservation projects across BC worth $5.7 million. Created by the provincial government in 1996, the HCTF operates with an independent board of directors that makes funding decisions based on technical advice from biologists both within and outside government.
- The Western Hemisphere Shorebird Reserve Network is a voluntary coalition of public and private agencies, land owners, and conservation groups, created in 1985 to identify shorebird habitat and to promote the conservation of critical breeding, migratory, and overwintering sites for shorebirds. The network has 60 sites that are designated and managed for shorebird habitat in eight countries. A 31,600-ha portion of the Fraser River estuary was added to the network in January 2005. (*www.manomet.org/WHSRN/*)
- The Canadian Parks and Wilderness Society is building support through the Marine Spaces campaign and the Baja California to Bering Sea initiative for establishment of an MPA network along North America's Pacific coast (CPAWS 2005b). See their website for publications on protected areas, vulnerable marine areas to consider for protection, and general information on marine conservation in BC. (*cpawsbc.org/publications/marine/index.php*)
- World Wildlife Fund Canada is building partnerships among stakeholders for establishing new MPAs, such as the proposed Gwaii Haanas National Marine Conservation Area and the Bowie Seamount MPA (WWF-Canada 2005). (*www.wwf.ca*)
- The Living Oceans Society has developed a statistical methodology, as part of the Marine Protected Area Design Project, for identifying high value areas on the Pacific coast that should be considered for legal protection (Living Oceans Society 2005). (*www.livingoceans.org*)
- The Orca Pass International Stewardship Area was proposed in 2002 as a coalition of citizen's groups from Washington State and British Columbia to promote stewardship of the transboundary area of Puget Sound and Strait of Georgia. The goal is to protect the marine environment by establishing a stewardship area that would be managed jointly by federal, state, provincial, and local governments, First Nations and residents, and user groups. (*www.georgiastrait.org/orcapass.php*)

WHAT CAN YOU DO?

- Join a local conservation organization and volunteer time to help them protect, conserve, or restore wild species and ecosystems.
- Donate money or land to a land trust. Several established trusts operate nationally, provincially, or locally.

  National trusts:

  - The Nature Conservancy of Canada protects threatened natural habitats and endangered species. (*www.natureconservancy.ca*)
  - Ducks Unlimited focuses on wetland conservation. Their BC branch is at *www.ducks.ca/province/bc/index.html.*

  Provincial trusts:

  - The Land Conservancy of BC protects properties with important plant and animal habitat, as well as properties with historic, cultural, scientific, and other values. (*www.conservancy.bc.ca*)
  - The Nature Trust of BC acquires and manages land to protect plants, animals, and their habitats. (*www.naturetrust.bc.ca*)
  - Many local trusts also operate in BC. A list of these, with contact information, is available from The Land Trust Alliance of BC, an umbrella organization that provides support to land trusts and conservancies and to other organizations and individuals. (*www.landtrustalliance.bc.ca*)
- Environment Canada's Ecological Gifts Program allows landowners to donate land or create a conservation covenant with a land trust or government. By doing so, landowners are eligible for benefits such as tax credits and reduced capital gains under Canada's Income Tax Act. These benefits apply to both individual and corporate donors. For information, see *www.cws-scf.ec.gc.ca/ecogifts/intro_e.cfm.*

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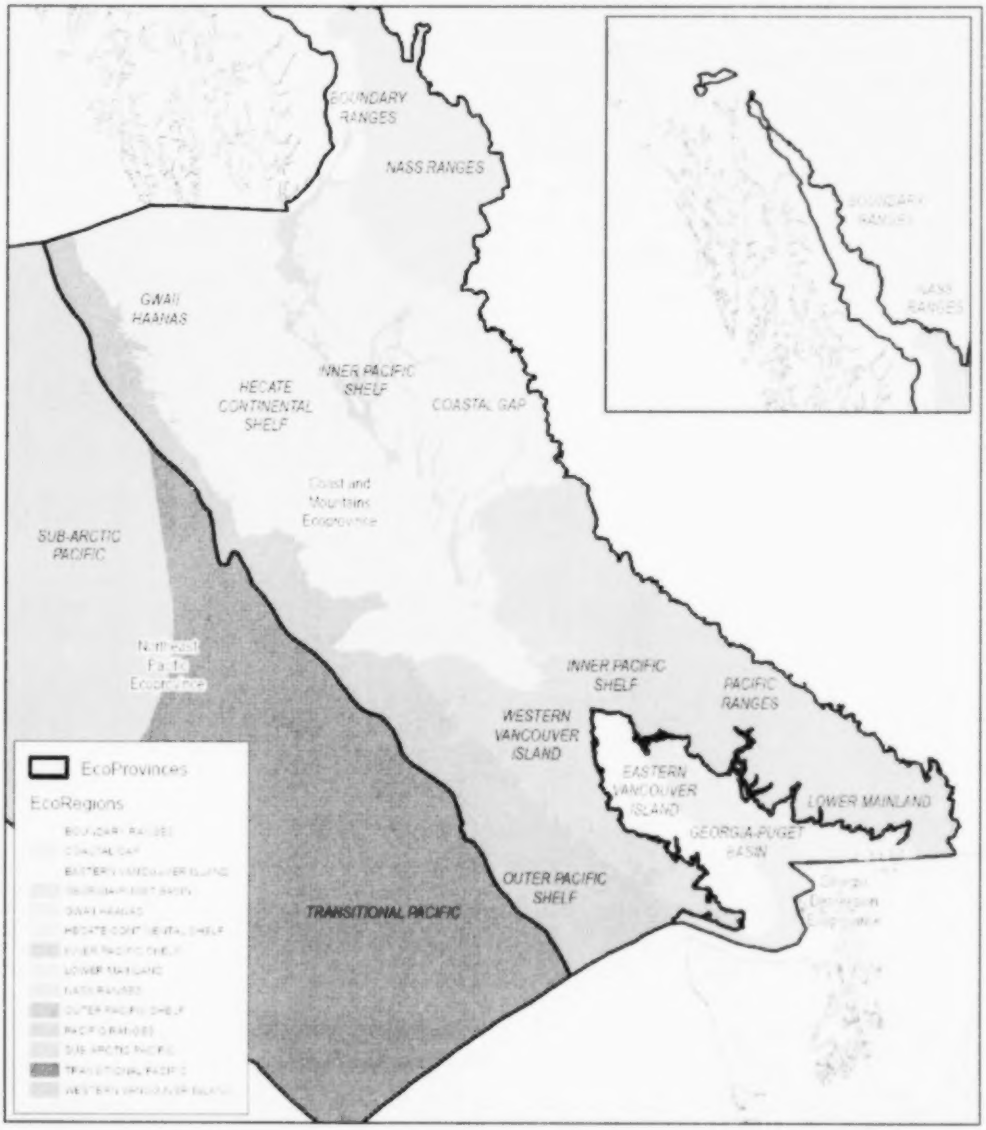
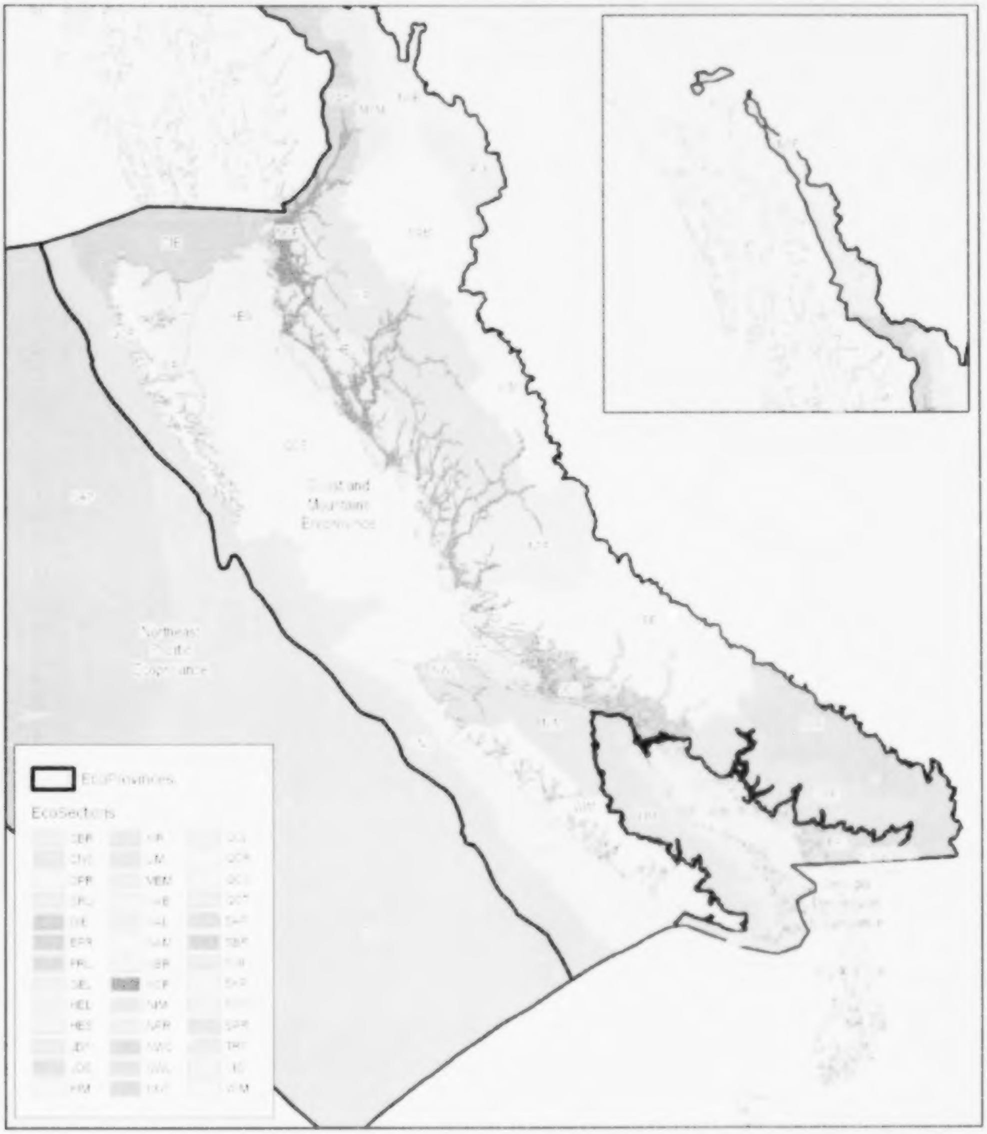
Appendix 1: Ecoprovinces and ecoregions of British Columbia.


BOUNDARY RANGES
NASS RANGES
GWAII HAANAS
HECATE CONTINENTAL SHELF
INNER PACIFIC SHELF
COASTAL GAP
Coast and Mountains Ecoprovince
SUB-ARCTIC PACIFIC
Northeast Pacific Ecoprovince
INNER PACIFIC SHELF
PACIFIC RANGES
WESTERN VANCOUVER ISLAND
EASTERN VANCOUVER ISLAND
LOWER MAINLAND
GEORGIA-PUGET BASIN
OUTER PACIFIC SHELF
TRANSITIONAL PACIFIC
Georgia Depression Ecoprovince
BOUNDARY RANGES
NASS RANGES
EcoProvinces
EcoRegions
BOUNDARY RANGES
COASTAL GAP
EASTERN VANCOUVER ISLAND
GEORGIA-PUGET BASIN
GWAII HAANAS
HECATE CONTINENTAL SHELF
INNER PACIFIC SHELF
LOWER MAINLAND
NASS RANGES
OUTER PACIFIC SHELF
PACIFIC RANGES
SUB-ARCTIC PACIFIC
TRANSITIONAL PACIFIC
WESTERN VANCOUVER ISLAND

Source: Integrated Land Management Bureau, Ministry of Agriculture and Lands.

Appendix 2: Ecoprovinces and ecosections of British Columbia.


Coast and Mountains Ecoprovince
Northeast Pacific Ecoprovince
EcoProvinces
EcoSections
CBR
CPR
EPR
DEL
HEL
HES
KIM
LIM
VEM
NIM
NPR
QCT
SBR
SPR

Source: Integrated Land Management Bureau, Ministry of Agriculture and Lands.

Ecosection codes

CBR	Central Boundary Ranges	KIR	Kitimat Ranges	QCL	**Queen Charlotte Lowland**
CNS	Continental Slope	LIM	Leeward Island Mountains	QCR	Queen Charlotte Ranges
CPR	**Central Pacific Ranges**	MEM	Meziadan Mountains	QCS	Queen Charlotte Strait
CRU	Cranberry Upland	NAB	**Nass Basin**	QCS	Queen Charlotte Sound
DIE	Dixon Entrance	NAL	Nanaimo Lowland	SAP	Subarctic Pacific
EPR	Eastern Pacific Ranges	NAM	Nass Mountains	SBR	Southern Boundary Ranges
FRL	Fraser Lowland	NBR	Northern Boundary Ranges	SGI	Southern Gulf Islands
GEL	Georgia Lowland	NCF	North Coast Fjords	SKP	Skidegate Plateau
HEL	Hecate Lowland	NIM	Northern Island Mountains	SOG	Strait of Georgia
HES	Hecate Strait	NPR	Northern Pacific Ranges	SPR	Southern Pacific Ranges
JDF	Juan de Fuca Strait	NWC	**Northwestern Cascade Ranges**	TRP	Transitional Pacific
JOS	Johnstone Strait	NWL	Nahwitti Lowland	VIS	Vancouver Island Shelf
KIM	Kimsquit Mountains	OUF	Outer Fjordland	WIM	Windward Island Mountains

Biodiversity

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Biodiversity

BACKGROUND

Global Biodiversity

Biodiversity, which comes from shortening the term "biological diversity," is defined as the number, variety, and interdependence of living organisms on the planet, as well as the ecosystems of which they are a part. The conservation of biodiversity, first recognized in the early 1980s (Wilson 1988), provides economic, scientific, cultural, and aesthetic values, but its greatest value is in maintaining the life-sustaining systems of the biosphere (UNEP 1992).

The first effort at assessing the global status of biodiversity produced a report in 1992 (World Conservation Monitoring Centre 1992). In 2005, another global assessment conducted by many of the same organizations reported that humans have depleted 60% of the world's grasslands, forests, farmlands, rivers, and lakes (MEA 2005a). They also reported that human activity is putting such a strain on the natural ecological functions that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted (MEA 2005a). In terms of the global state of organisms, 33% of amphibian species (Stuart et al. 2004), 12% of birds (Birdlife International 2004), and 23% of mammals (IUCN 2003) are considered vulnerable, endangered, or critically endangered. Estimates of the global rate at which organism are becoming extinct range from 100 to 1000 times the historically "normal" rate of extinction, and scenarios for the future suggest this may increase a further 10 times (UNEP 2001; MEA 2005b). This accelerated extinction is the result of human activities such as altering and destroying habitat, pollution, over-harvesting species, introducing non-native species, and producing greenhouse gases that are causing a changing climate (Wilson 1992). Globally, the pressures on biodiversity are expected to continue or increase, further compromising the ability of these ecosystems to support human life (MEA 2005a, 2005b).

Coastal Biodiversity in BC

Marine coastal ecosystems are among the most productive and diverse communities in the world (Poore and Wilson 1993). It is not surprising that British Columbia, with its extensive coastline and complex glacial history, is one of the most biologically diverse provinces in Canada. British Columbia occupies 10% of Canada's land area while containing more than half of Canada's vertebrates and vascular plants and three-quarters of its bird and mammal species (BCMELP 1993).

Coastal BC is the most biologically diverse area of the province. An impressive 78% of all the mammal species in BC (D. Nagorsen, unpubl. data compiled for BC Ministry of Environment, 2004), 64% of the birds that regularly breed in BC (R. Cannings, unpubl. data compiled for BC Ministry of Environment, 2004), 64% of BC's amphibians (Green

1999), 69% of BC's reptiles (Gregory and Gregory 1999), and 67% of BC's freshwater fish species (McPhail and Carveth 1994) are found on the coast. Even more compelling is the extent to which endemic (meaning locally unique and native) species occur on the coast:

- Two-thirds of the mammal species and subspecies that are found only in BC occur nowhere else in the province but the coast (D. Nagorsen, unpubl. data compiled for BC Ministry of Environment, 2004).
- Three-quarters of the subspecies and significant populations of freshwater fish found only in BC are exclusive to the coast (McPhail and Carveth 1994; BC Ministry of Environment, unpub. data, 2004).
- All of the bird subspecies that breed only in BC do so exclusively on the coast (R. Cannings, unpubl. data compiled for BC Ministry of Environment, 2004).
- Approximately 10% (238 of a total 2316) of the province's vascular plant taxa, including subspecies and varieties, occur only on the Pacific coast between Alaska and Mexico (Douglas et al. 2002).

The rugged BC coast, with its characteristic fiords and islands, provides an environment that hastens the divergence of species by separating and isolating populations. As time goes by, isolated populations grow more adapted to their local environment and, in doing so, diverge in appearance or behaviour from other populations of their species. It is not surprising that 44 of the 62 vertebrate subspecies and significant populations endemic to coastal British Columbia occur on coastal islands (including Vancouver Island). In the Queen Charlotte Islands alone, 8 of the 12 coastal endemic breeding birds occur, including local variants of Stellar's jay.

The biodiversity of coastal British Columbia is of global importance. The province's remaining old-growth coastal rainforest represents approximately one-quarter of all remaining coastal temperate rainforests worldwide (BCMOF 2004). These forests are rare globally, yet they have exceptionally high biological production and biological diversity. In addition, the province bears some of the global responsibility for at least 19 coastal species that, in addition to being at risk in BC, are also at risk globally (CDC 2005). Examples include the Oregon spotted frog (*Rana pretiosa*), an aquatic native of the Fraser Valley; the Cowichan lake lamprey (*Lampetra macrostoma*), a primitive fish found only in two lakes on Vancouver Island; and Keen's long-eared myotis (*Myotis keenii*), a small bat that occurs in hot springs on the Queen Charlotte Islands.

Conserving Biodiversity

Several key organizations provide information on biodiversity conservation in British Columbia. At the national level, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is an independent body of experts who use scientific, aboriginal, and community knowledge to classify species as extirpated (extinct in a local area, province, or country), endangered, threatened, or of special concern (see text box). COSEWIC has listed more than 450 plant and animal species as being at risk in Canada, meaning that their continued existence in this country is in danger (Environment Canada 2004). Of the 450 species listed by COSEWIC, 119 occur in coastal British Columbia. Four of these species are extirpated: the Island marble butterfly (*Euchloe ausonides*), Puget Oregonian snail (*Cryptomastix devia*), Pacific gophersnake (*Pituophis catenifer catenifer*), and Pacific pond turtle (*Actinemys marmorata*).

COSEWIC CLASSIFICATIONS FOR WILD SPECIES IN CANADA

- Extinct: A species that no longer exists.
- Extirpated: A species that no longer exists in the wild in Canada, but occurs elsewhere.
- Endangered: A species facing imminent extirpation or extinction.
- Threatened: A species expected to become endangered if limiting factors are not reversed.
- Special concern: A species that may become threatened or endangered for a combination of reasons, such as biological characteristics, or particular threats.
- Data deficient: A species for which there is inadequate information to make an assessment of its risk of extinction (COSEWIC 2004).

The BC Conservation Data Centre (CDC) is a government body that annually publishes the provincial lists of species considered by provincial biologists to be endangered or threatened (red list), or of conservation concern (blue list) (see text box). As of 2005, the red list contained 237 organisms and the blue list, 203 organisms. This includes vertebrates, vascular plants, freshwater fishes, and a small number of invertebrates (butterflies, dragonflies, some gastropods, and molluscs). Species on the red or blue lists may also be legally designated as extirpated, endangered, or threatened under the Wildlife Act. CDC is housed within the provincial government, but is also part of NatureServe, an international organization of cooperating conservation data centres and natural heritage programs, all using the same methodology to gather and exchange information on the threatened elements of biodiversity.

SPECIES AT RISK IN BRITISH COLUMBIA

The **Red List** includes species that are:

- legally designated as threatened or endangered under the provincial Wildlife Act. As of 2005, legally designated species included the sea otter (*Enhydra lutris*), which is threatened, and the following endangered species: American white pelican (*Pelicanus erythrorhyncos*), burrowing owl (*Athene cunicularia*), and Vancouver Island marmot (*Marmota vancouverensis*).
- candidates for such designation. These are the vast majority of species on the list.
- extirpated or extinct.

The **Blue List** includes species not immediately threatened but of concern because of characteristics that make them particularly sensitive to human activities or natural events.

The **Yellow List** includes uncommon, common, declining, and increasing species—all species not included on the red or blue lists, but tracked by the Conservation Data Centre.

As a signatory to the 1996 Accord for the Protection of Species at Risk, British Columbia committed to supporting the recovery of threatened and endangered species in the province. Until the federal Species at Risk Act (SARA) was proclaimed in June 2003, however, no legislation specifically protected Canadian species at risk. SARA has three goals: (i) to prevent Canadian indigenous species, subspecies, and distinct populations from becoming extinct or extirpated (locally extinct); (ii) to provide for the recovery of endangered or threatened species; and (iii) to encourage the management of other species to prevent them from becoming at risk. To list a species under SARA, COSEWIC recommends it to the Minister of Environment based on a status assessment. After a period of public consultation, the federal Cabinet considers the recommendation, taking into account social, political, and economic factors, and decides whether the species should be added to the legal list of species at risk (Government of Canada 2005). SARA requires that a recovery strategy and an action plan be prepared for any extinct, endangered, or threatened species listed under the act; management plans, which are less stringent in terms of content, are necessary for species of special concern. The federal minister is required to report on the progress of implementing each strategy and plan.

This paper presents indicators of biodiversity on the coast of British Columbia. It focuses on the status and population trends of coastal species and on progress in recovery planning for species at risk. Indicators showing the impact of specific human activities on ecosystems and wildlife are discussed in the other project papers.

INDICATORS

1. Key Indicator: Changes in the conservation status of threatened and endangered vertebrates of the BC coast

This is a state or condition indicator. It addresses the question: What is the status of key coastal species?

Conservation status of species, usually summarized as the proportion of native species that are at risk, is widely used as the basis for tracking biodiversity. It is used nationally and internationally by Canada (Environment Canada 2003), the United States (Heinz Center 2002), Denmark, Japan, Italy,England, and other countries (cited in Saunders et al. 1998), and by global organizations such as the World Conservation Union (IUCN 2003). Despite their widespread use, however, indicators that summarize conservation status have been criticized, primarily because changes in knowledge of a species and how its status is assessed can mask actual changes in the status of the species (Possingham et al. 2002; Keith and Burgman 2004).

Changes in the number of species at risk, or the percentage of known species that are on the BC red list, occur as a result of changes in:

- organism taxonomy (e.g., single species are "split" into multiple species, or multiple species are "lumped" into one);
- methods for assessing risk or assigning risk categories (e.g., the procedure for assessing status is changed);
- knowledge of a species status (e.g., new information about a species may show that it is at greater or lesser risk than had been previously assumed);
- actual species status (e.g., the real abundance or distribution of a species has changed).

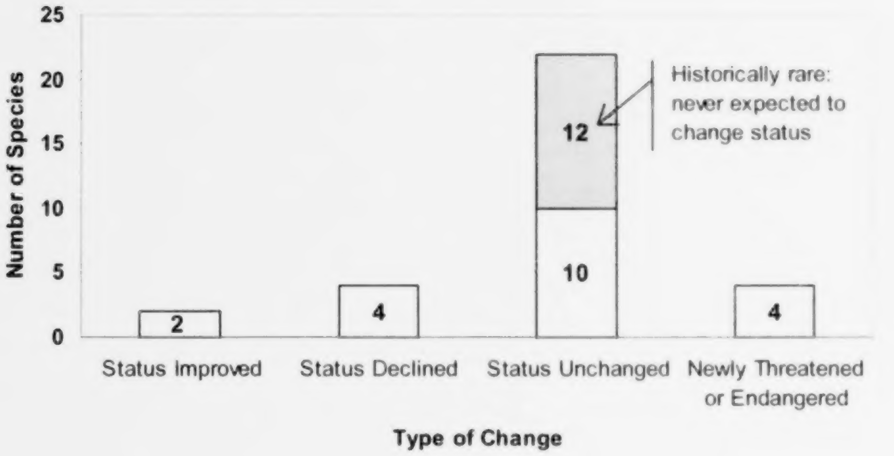
It is commonly assumed that a change in conservation status is primarily a product of changes in the actual species status. However, a BC study has shown that the first three factors listed above are more significant determinants of change in the numbers of species at risk than real changes in the actual status of the species (Quayle and Ramsay 2005). To address this problem and improve on previous indicators, a new indicator was developed for threatened and endangered species in British Columbia. The indicator corrects for changes in taxonomy, assessment methods, and increased knowledge. It lists only the actual change in the status of the red-listed species.

For discussion purposes, the term "species" is used interchangeably with the term "taxon" (pl: taxa) to include the full scope of species, subspecies, and significant populations that are the focus of conservation listing in British Columbia and Canada.

Methodology and Data

The BC Conservation Centre (CDC) published its first red list in 1992. The analysis for this indicator therefore covered the 12 years from 1992 to 2004. Changes in the red list were based on changes in the subnational rankings (S rank) of individual species, as tracked by the CDC. The S ranks generally range from S1 (critically imperilled) to S5 (secure) (Figure 1). Species with an S rank of S1, S2, or S1S2 are considered threatened or endangered in British Columbia. The analysis was limited to mammals, birds, amphibians, reptiles, and freshwater fishes that occur in the Georgia Depression and Coast and Mountains ecoprovinces of British Columbia. Although assessed by CDC as threatened or endangered, species on the provincial red list are not necessarily legally designated as such. Quayle and Ramsay (2005) contains a detailed description of how data were compiled and analyzed.

Figure 1. Changes in the status of red-listed mammals, birds, reptiles, amphibians, and freshwater fishes for coastal British Columbia, 1992-2004. Data exclude four taxa already known to be extirpated as of 1992.



Source: Original data from CDC, Ministry of Sustainable Resource Management 2004. Adapted from Quayle and Ramsay (2005).

Note: Twelve of the 22 species with Status Unchanged are historically rare (i.e., never expected to change status for the better). Status Declined includes two new subspecies extinctions.

Interpretation

This indicator focused on vertebrates because they are the best understood taxa in the province and are possibly less subject to artificial fluctuations in status resulting from changes in our knowledge of their status (Possingham et al. 2002). Although plants and invertebrates make up most of the province's biodiversity, the vertebrate results are likely to be indicative of coarse changes in other taxonomic groups. This is because the same type of pressures that affect vertebrates—such as habitat destruction or climate change—would also affect other organisms.

Of the 10 red-listed species that experienced a real change in status, only two showed improvement. These were the sea otter (*Enhydra lutrus*) and the purple martin (*Progne subis*), a migratory swallow that suffers from competition for nest cavities with invasive birds. The martin increased in numbers as a result of nest box construction programs; it remains threatened in the province because of its dependence on these human-made structures (Pridgeon 1997).

Four coastal species that were already red-listed experienced a further decline in status between 1992 and 2004. All four species appear to have been vulnerable because they were isolated. Two subspecies of stickleback (*Gasterostereus* spp.) confined to Hadley Lake are now extinct because non-native catfish, which prey on stickleback eggs, were introduced to the lake (Backhouse 2000). The Vancouver Island wolverine (*Gulo gulo vancouverensis*), a subspecies of wolverine exclusive to Vancouver Island, went from imperilled (S2) in 1992 to historic (SH) in 2002, because it has not been seen for decades (Cannings et al. 1999). The Vancouver Island marmot, a large rodent endemic to alpine areas of Vancouver Island, moved from imperilled (S2) to critically imperilled (S1); only 30 individuals were living in the wild in 2004 (Environment Canada 2005).

Four coastal taxa were added to the provincial red list between 1992 and 2004. Two are populations of killer whales (*Orca orcinus*) and two are bird species. Marbled murrelets (*Brachyramphus marmoratus*) have suffered from loss of their old-growth forest breeding habitat (Hull 2000). Double-crested cormorants (*Phalacrocorax auritius*) have declined recently, apparently because disturbance by bald eagles is causing the adults to flee their nesting sites, leaving the nests vulnerable to predatory gulls and crows (Moul and Gebauer 2002). This pattern may result from an increase in bald eagle numbers or a reduction in fish stocks on which the eagles prey.

Most striking about these results is how little change there has been in actual status of coastal vertebrate species since 1992. Taxa that are naturally rare may account for some of this, because historically they have had populations or distributions in BC that would make them red-listed species even in a pristine landscape. Of the 22 species that experienced no change in status, 12 of these (>50%) appear to be naturally rare. Most of these 12 are confined by very specific and rare habitats. For example, 7 fish taxa are found only in one BC lake and a subspecies of Townsend's vole (*Microtus townsendii cowani*) is found only on Triangle Island. Although modern threats to these 12 species might be mitigated, barring their extirpation or a historically unprecedented change in distribution or numbers, these 12 species will remain on the BC red list indefinitely.

Incorporating the concept of natural rarity shifts the baseline for this indicator away from zero to approximately 12 coastal vertebrate species that are unlikely to show improvement in status. It does not diminish the importance of the 10 remaining species that now appear on the red list because of their unnaturally small numbers or contracted distribution. For example, populations of the spotted owl (*Strix occidentalis*), which was on the red list in both 1992 and 2002, have declined by half over that time (Blackburn et al. 2002). Population trends are unknown for most other species that have been on the red list since 1992, although absolute population numbers are low (Cannings et al. 1999). Population recovery is a slow process, however, particularly for the many vertebrates that produce only a few young each year. Even for most species that have shown improvement, the 12-year period covered by this indicator is not long enough for the degree of recovery that would enable them to be removed from the red list. This may also explain why the indicator does not yet show an effect of the 1996 federal Accord for the Protection of Species at Risk.

Analysis shows that only 10 of the 30 (33%) changes in the rankings of red-listed vertebrates in coastal BC between 1992 and 2004 represented actual changes in species status. The remainder were due to changes in taxonomy, knowledge, or assessment methods. Although this bias was removed in the calculations for this indicator, the large proportion of change that was found to be due to external factors—unrelated to the real status of the species—emphasizes the need for better quality data. The strength of the indicator relies on high-quality monitoring data about the species considered for, and included on, the red list (Quayle and Ramsay 2005; Heinz Center 2002).

Supplementary Information: Species at Risk and Rare Invertebrates

Species at Risk on the Pacific Coast

In 2005, 119 of the animal and plant species that occur on the BC coast were listed as nationally at risk by COSEWIC (Table 1). In addition, 357 species on the provincial red and blue lists (equivalent to endangered or threatened, and special concern, respectively) were also found on the coast.

National and provincial status assessments are not complete over the full range of species. Most notably, only a portion of the invertebrates and non-vascular plant species have been assessed. Assessment of vascular plants is also limited at the national level. For the first time the status of all Pacific marine fishes is due for publication later in 2006.

Provincial red and blue lists include 119 ecological communities at risk in the province that potentially occur on the coast. Ecological communities are assemblages of plant species that can occur together and have the potential to interact with one another. Ecological communities include natural plant communities and plant associations and the full range of ecosystems that occur in British Columbia (for more information, see: *www.env.gov.bc.ca/cdc/ecology/index.html*).

Table 1. The status of species at risk on the Pacific coast in Canada and British Columbia.

	Listed in Canada				Listed in British Columbia		
	Endangered	Threatened	Special concern	Canada total	Red list (endangered threatened)	Blue list (special concern)	BC total
Amphibians	1	1	3	5	2	2	4
Butterflies/ dragonflies	3	1	1	5[a]	7	12	19
Birds	2	5	8	15	18	20	38
Freshwater fishes	10	2	3	15	14	5	19
Marine fishes	4	1		5[b]	–	–	–
Mammals	6	7	8	21	14	11	25
Molluscs[b]	2	2	2	6	1	0	1
Reptiles	2		1	3	3	1	4
Vascular plants	21	8	2	31[b]	102	145	247
Species total	**51**	**27**	**28**	**106**	**161**	**196**	**357**
Ecological communities	–	–	–	–	69	50	119[c]
Grand total	**51**	**27**	**28**	**106**	**230**	**246**	**476**

Source: Canadian data: COSEWIC 2005. British Columbia data: CDC 2005.

Note: Data on the status of algae, mosses, and marine invertebrates are not reported.

[a] Assessment limited to butterflies.

[b] Assessment of species group is largely incomplete.

[c] Analysis of ecological communities in BC limited to Coastal Douglas Fir, Coastal Western Hemlock, Mountain Hemlock, and Alpine Tundra biogeoclimatic zones.

– indicates Not Assessed.

Rare invertebrates

Invertebrates include insects, molluscs, spiders, crustaceans, millipedes, and centipedes. In an analysis of the province's freshwater and terrestrial invertebrates, Scudder (1996) lists the Georgia Basin, Vancouver Island, Queen Charlotte Islands, and the Lower Mainland as the highest priority areas for conservation of rare and endangered invertebrates. In a separate analysis in the same report, the Coastal Douglas Fir biogeoclimatic subzone was ranked as the province's highest priority ecological zone for conserving rare and endangered invertebrates.

In an analysis of marine invertebrates, Austin (2000) identified 50 species of rare marine invertebrates (i.e., known from five or fewer provincial records) on the British Columbia coast (Table 2). The list includes species that occur at the edge of their range in BC, but are common elsewhere, and species that are rare in BC waters as well as in other seas. This was not an exhaustive list, but approximately 30% of the species were found in places that are designated or proposed for some type of protection (the extent of protection varies). Two species, a sand dollar and a sea star, that were collected from the coast in the early 1900s, have not been reported since and may now be extirpated from BC waters.

Table 2. Taxonomic distribution of 50 species of marine invertebrates identified as rare along the BC coast, by phylum.

Phylum	Description	Number of rare species identified
Porifera	Sponges	7
Cnidaria	Stinging thread animals (hydroids, corals, anemones)	4
Platyhelminthes	Flatworms	1
Echinodermata	Spiny skinned animals (stars, cucumbers, urchins)	9
Hemichordata	Acorn worms and allies	1
Brachiopoda	Lamp shells	2
Chordata	Vertebrates and allies	4
Mollusca	Soft bodied animals (cradles, limpets, snails, sea slugs, mussels, scallops, clams)	13
Pogonorpha	Beard worms	1
Annelida	Segmented worms	1
Arthropoda	Joint legged animals (centipedes, spiders, barnacles, crabs, shrimp)	7

Source: Austin (2000).

2. Secondary Indicator: Trends in abundance of killer whale populations along the BC coast

This is a status or condition indicator. It addresses the question: What is the status of a key coastal species?

The killer whale (*Orcinus orca*) is only one of 25 species of cetaceans (whales, dolphins, and porpoises) found along the BC coast (Nagorsen 2003), but it is a particularly high-profile species. Because of their relatively large size, distinctive appearance, and the publicity they receive, killer whales are widely known and recognized. Watching killer whales is now a multimillion dollar industry in Johnstone Strait, Juan de Fuca Strait, Strait of Georgia, and Puget Sound. The status of killer whale populations is an indicator of the health of coastal ecosystems because whales need clean water, healthy prey populations, and an environment that is large and quiet enough for them to maintain communication, locate and capture prey without disruption, and maintain other vital life functions (Killer Whale Recovery Team 2005).

Although the killer whale is generally considered one species, three distinct forms or ecotypes inhabit the coast of BC: transient, offshore, and resident (Killer Whale Recovery Team 2005). There are two different populations of the resident whale ecotype: southern residents and northern residents. One of the most important differences between ecotypes is diet: resident whales appear to feed almost entirely on fish, and transients appear to feed almost entirely on marine mammals (Ford et al. 1998). Less is known about offshore killer whales, but they are also thought to feed on fish (Ford et al. 2000; Heise et al. 2003, cited in Killer Whale Recovery Team 2005). Offshore and resident whales travel in large groups, using frequent echolocation and social calls. Transients rely on stealth to catch their prey and travel alone or in small, quiet groups (Killer Whale Recovery Team 2005).

The southern residents appear to be the most endangered, but all killer whale populations along the BC coast are considered to be at risk according to both federal and provincial criteria (see Table 3). A species recovery strategy has been drafted for the northern and southern resident populations.

Table 3. Status of killer whale groups on the Pacific coast.

Population / ecotype	Federal status	BC provincial status
Southern resident	Endangered	Red list
Northern resident	Threatened	Red list
Transient	Threatened	Red list
Offshore	Special concern	Blue list

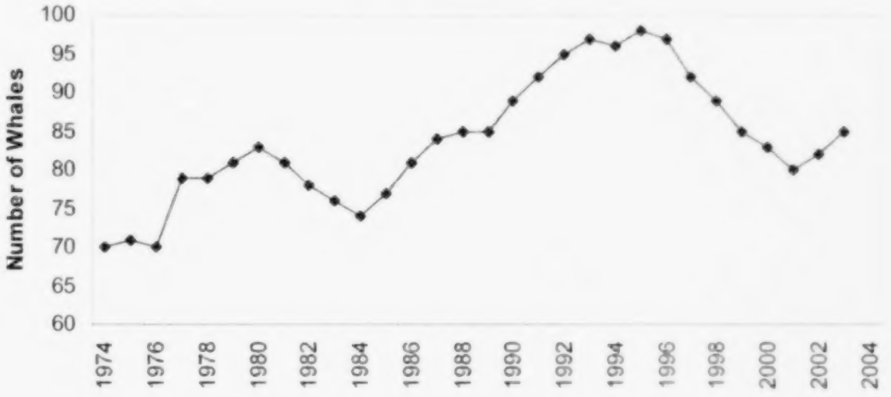
Methodology and Data

Population counts of killer whales are made annually. The Center for Whale Research, San Juan Island, carries out the census for the southern residents; the Cetacean Research Program, Department of Fisheries and Oceans Canada (DFO), Nanaimo, carries out the census for the northern residents. During vessel surveys, photographs are taken of all whales encountered. Individual whales are identified by program staff from a database of photographs. Each whale is identified by its uniquely shaped dorsal fin and saddle patch, as well as by scars.

The southern resident count includes all whales that are seen during a calendar year, and mortalities may be included in the count, depending on when they occur. For example, a whale that is not seen after March in a given year is assumed to be dead. However, because whales may leave inshore waters in winter, it is not certain that whales not counted in November or December are dead; therefore, such whales may still be included in the count for that year (Killer Whale Recovery Team 2005). In recent years, observer effort has been high and members of the southern resident population are photographed annually, so that the count is expected to be reasonably accurate. There are small discrepancies in the southern resident counts in the literature due to different methods of recording when whales are considered to enter or leave the population (e.g., Krahn et al. 2004 reported 83 southern residents in 2003, whereas Figure 2 shows 85.)

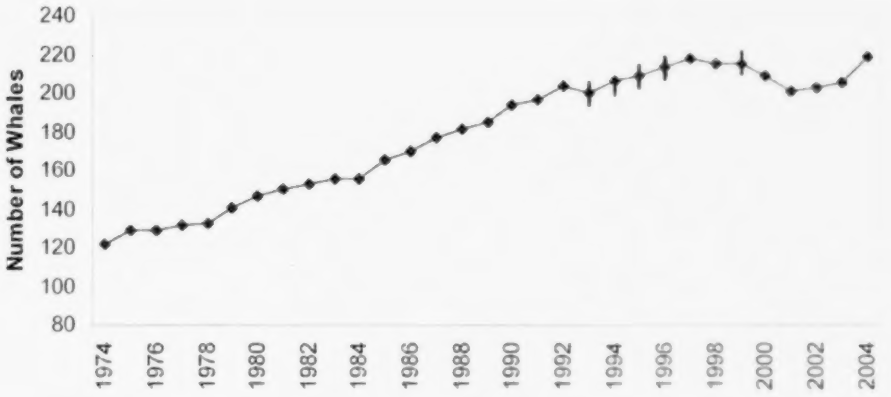
The northern resident count includes all whales that are known to be alive in July-August of each year, and the annual population is estimated from that number (Killer Whale Recovery Team 2005). However, not all members of the northern resident community are seen each year because they travel widely along the BC coast, so the counts are generally less accurate than for the southern residents.

Figure 2. Population size and trend for southern resident killer whales of the BC coast, 1974–2004.



Source: Center for Whale Research, Friday Harbor, Washington, USA, unpubl. data.

Figure 3. Population size and trend for northern resident killer whales of the BC coast, 1974–2004.



Source: Cetacean Research Program-DFO, Nanaimo, unpubl. data.
Note: Bars represent uncertainty due to some groups not being seen in some years.

Interpretation

According to the Killer Whale Recovery Team (2005), in 2003 there were a total of 290 northern and southern resident killer whales, and approximately 220 transient and 200 offshore killer whales. Little is known about the historic abundance of killer whales, and there are no population estimates for killer whales in British Columbia before 1960. In the late 1960s and early 1970s, a total of 47 individuals that were known to be (or likely to have been) southern residents were captured and sent to aquaria (Bigg et al. 1990). This may have represented 40% of the total population at the time, calculated by adding the number of whales captured to the number counted in 1974.

After live captures ended in 1973, the population of southern residents increased to 83 by 1980 (Figure 2). However, the population declined in the early 1980s as a result of lower birth rates, higher mortality for adult females and juveniles, and lower numbers of mature animals, especially males, caused by the selective live captures before 1973 (Olesiuk et al. 1990; Killer Whale Recovery Team 2005). After a surge in the number of breeding individuals, the population increased 34% over the next decade to 99 animals. The latest decline, which began in 1996, now appears to be reversing in some groups within the population, but not in others. New research strongly linking the abundance of Chinook salmon to the population dynamics of resident killer whales suggests that prey limitation may be an important factor in recent declines (Ford et al. 2005).

Currently, the number of southern resident whales is still below the numbers estimated before the live captures occurred (Baird 1999). An analysis of population viability, taken from just the 1990 reproductive rates, would indicate that extinction of southern residents is inevitable. In contrast, analyses based on the longer 1974–2000 average indicate that the risk of extinction is much less (0–55% probability; summarized in Killer Whale Recovery Team 2005). The risk of extinction could be even lower if southern residents are part of a larger breeding population of northern BC and southern Alaska residents (Krahn et al. 2002), but current evidence suggests that the southern residents are genetically isolated (Barrett-Lennard and Ellis 2001).

At least 14 whales were known to have been taken from the northern resident population between 1964 and 1973; 12 of these were from one pod (Bigg et al. 1990). In contrast to the southern population, the northern population appears to have grown steadily from 1974 to 1991 (Figure 3). This may have been because the northern population was larger to begin with, because fewer individuals were captured, or because they are generally exposed to less disturbance (Killer Whale Recovery Team 2005). As with the southern residents, evidence suggests that population declines in the late 1990s are related to a reduction in overall numbers of a key prey species, the Chinook salmon, along the west coast (Ford et al. 2005).

The small size of both northern and southern resident killer whale populations makes them particularly vulnerable to threats, such as environmental contaminants (including oil spills), reduced availability of prey, disturbances, and noise pollution. Even under ideal conditions, killer whale populations tend to recover slowly because mature females calve only every 5–6 years (Killer Whale Recovery Team 2005).

3. Secondary Indicator: Observed abundance of coastal waterbirds

This is a status indicator. It addresses the question: What is the status of our coastal birds?

Globally, the conservation status of marine birds has declined sharply; nearly one-third of the bird species that depend on marine and coastal areas are currently considered to be threatened (Butchart et al. 2004; MEA 2005c). The coastal habitats of British Columbia support some of the highest densities of seabirds, waterfowl, shorebirds, and raptors in the eastern North Pacific (Butler and Vermeer 1994), including globally significant populations of breeding, migrant, and wintering species.

The Strait of Georgia is a key area for wintering and migratory species, particularly the Fraser Delta, including Boundary Bay and Roberts Bank, and the east coast of Vancouver Island from Nanoose Bay north to the Comox estuary. The Fraser River estuary—which supports well over 2 million migratory shorebirds and waterfowl annually—was recently designated as a Western Hemisphere Shorebird Reserve. Outside the Georgia Basin, Rose Spit at the northeastern tip of the Queen Charlotte Islands also supports significant winter concentrations of some shorebird and auk species.

Two-thirds of British Columbia's human population and three-quarters of its labor force live in and around the Georgia Basin. Waterbirds and their habitats in this region are subject to a wide range of anthropogenic influences including recreation, seashore industry, residential development, and marine vessel traffic (Vermeer 1994). Each influence has associated negative effects, including disturbance, effluent discharges from industry, sewage overflow, and oil spills from ships. Several internationally designated Important Bird Areas in the Strait of Georgia are close to major population centres with substantial industry and shipping activity, and many waterbird populations use habitats that lie along or adjacent to major oil shipping lanes and are therefore at risk from discharges of oil.

The BC Coastal Waterbird Survey was established by Bird Studies Canada and the Canadian Wildlife Service to provide baseline species distribution data and to monitor changes in waterbird populations throughout British Columbia. The survey is a volunteer-based program focusing on the populated areas of the Lower Mainland and on islands in the Strait of Georgia. The Georgia Basin Action Plan provided funding for analyses.

Methodology and Data

Skilled volunteers count the number of waterbirds and raptors at specific sites within two hours of the high tide. Volunteers follow a standard protocol and count on predetermined dates (or one day before or after these dates) each month from September through April, for a total of eight monthly visits per winter. Species groups surveyed include loons, grebes, cormorants, herons, swans, geese, ducks, shorebirds (sandpipers, plovers, etc.), gulls, alcids (murres, puffins, etc.), and raptors. The number of surveyed sites ranges from 171 to 207, with an average of 180 sites surveyed.

Indices of relative abundance were developed for the first five winters (1999/2000, 2000/01, 2001/02, 2002/03 and 2003/04), based on the mean count of each species at each survey site in each winter (Badzinski et al. 2005). Preliminary population trend assessments were conducted for the 58 most commonly recorded species, using linear regression models to estimate changes in relative abundance over the five-year period (Table 4). An analysis was also conducted on the five-year dataset to assess the survey's ability to detect annual population changes of less than 3% for each of the 58 species.

Table 4. Number of coastal waterbird species by species group, showing significant ($p < 0.05$) upward or downward trends between 1999/2000 and 2003/04.

	Five-year trend			
Species group	Significant upward trend	Significant downward trend	Trend not significant	Total
Cormorants	2	0	1	3
Grebes	1	1	1	3
Gulls	2	1	4	7
Herons	1	0	0	1
Loons	1	0	2	3
Raptors	0	2	2	4
Seabirds	0	1	2	3
Shorebirds	1	1	6	8
Waterfowl	5	5	16	26
Total	12	12	34	58

Source: Coastal Waterbird Survey, Badzinski et al. 2005.

Interpretation

The five-year trends shown in Table 4 should be considered as preliminary, given the short time over which the survey has been conducted, the non-random selection of survey sites and naturally wide fluctuations that occur in waterfowl populations (Wilkins and Otto 2003). Although it was not possible to detect trends for most of the species counted, the numbers of wintering long-tailed duck (*Clangula hyemalis*) showed one of the strongest declining trends of any species counted in the survey. This agrees with other species-specific surveys, which have shown substantial declines in some sea duck species, including scoters and long-tailed ducks, over the last 30 years (USFWS 1999).

Analyses of the data showed that with five years of data (six winter seasons), population trends could be adequately detected for only a few of the species most commonly recorded. By analyzing the statistical power of the results, it appears that after 10 years of data, it would be possible to detect significant population trends for about two-thirds of the most commonly recorded species. This would require maintaining high levels of volunteer coverage over 10 years and possibly other improvements to the survey methodology. As it continues, the Coastal Waterbird Survey should fill a gap in bird population monitoring. It provides better coverage of coastal habitats than the Breeding Bird Survey (CWS 2004) and improves on the Christmas Bird Count, which does not differentiate coastal habitat within counts and does not test for significance of population trends (Audubon Society 2005).

4. Key Indicator: Number of alien species, by group, in coastal BC

This is a pressure indicator. It addresses the questions: How much of a problem are invasive species in BC? How many invasive species have been introduced to coastal BC?

Alien, or exotic, organisms live outside of their natural range usually because they have been deliberately or accidentally introduced there by humans. Because their natural predators or diseases are generally not present in the new environment, such introduced species can become established and reproduce quickly. According to one estimate, about 10% of introduced species become invasive (Menge and Branch 2001). Alien species are particularly effective at invading and becoming established in ecosystems under stress, such as those that are recently disturbed (Sorensen 1984).

Alien species may be second only to habitat destruction in causing the loss of biological diversity worldwide (Vitousek et al. 1997). Current efforts to manage alien species have generally not been effective in controlling the problem (Simberloff et al. 2005). Global trade provides an increasing number of opportunities to transport organisms into non-native habitats where they may prey on, compete with, or alter the value of habitat for native organisms (Simberloff 2002).

In addition to the cost of ecological destruction, managing alien species is expensive. Economic costs include lost agricultural production and ecosystem services, control or eradication programs, and exclusion programs to keep out possible invaders. Alien species in the United States are estimated to cause environmental loss and damage worth US$137 billion per year (Pimental et al. 2000).

Methodology and Data

Three separate datasets are presented in this indicator (Table 5).

1. Coastal Vertebrates: The Conservation Data Centre (CDC) of the BC Ministry of Environment tracks the occurrence of many animal species known to be introduced to coastal BC habitats from elsewhere in BC or Canada or from outside of Canada. The CDC's list of introduced species is not exhaustive because it excludes many marine organisms, as well as nonvascular plants (algae) and invertebrates other than butterflies, dragonflies, and damselflies. For this indicator, vertebrate species were included if they were present in coastal habitats. In some cases, a species was recorded as "introduced" if it is native to BC but now occurs in a coastal area (e.g., on an island) where it was not found historically. Insects were not included because data were only available on two species of butterflies, whereas many more alien insects are known.

2. Coastal Vascular Plants: Alien plant data were compiled from the UBC Herbarium Database (*www.botany.ubc.ca/herbarium/*), recent publications (Ceska 1997; Douglas et al. 1998-2002; Klinkenberg 2004), and expert knowledge (Roy Cranston, pers. comm.). Data include alien plant species that live in terrestrial, freshwater, marine, and estuarine habitats along the BC coast. All are believed to have become established on the coast. Alien plant species were categorized as either frequent (occurring widely in coastal habitats) or rare (known from five or fewer scattered sites). Rare species are those considered to be established although they are seldom found.

3. Strait of Georgia Species: Data on alien marine and estuarine plant and animal species just in the Strait of Georgia were extracted from Levings et al. (2002). These data were considered provisional and only the confirmed alien species were included in this indicator. Some of these species are known to be established; the long-term status of others is not known.

Interpretation

Plants are overwhelmingly the most common group of alien species documented in coastal BC (Table 5). About 65% of alien plants occur frequently and appear to be widely established. The number of alien plants is high, likely because they have been unintentionally imported along with livestock feed, as well as introduced for nursery and other agricultural purposes (Harding 1994). Others may have arrived on imports of equipment or on domesticated animals. Many of the most invasive plants (e.g., Scotch broom, purple loosestrife, baby's breath, Japanese knotweed) were intentionally planted as ornamentals and have escaped from gardens.

At least 35 of the 41 alien vertebrates established on the BC coast were introduced intentionally (Ministry of Environment, 2005, prelim. data). They may have been deliberately introduced for hunting and fishing (e.g., chukar, wild turkey, bass), intended to beautify the countryside (e.g., Eurasian skylark), set free from zoos (grey squirrel, European wall lizard), or released pets (e.g., red-eared slider turtle). Both federal and provincial governments continue to sponsor programs to stock alien species of sportfish in non-native habitats throughout coastal BC, despite research documenting this practice as a conservation threat to freshwater systems (e.g., Pilliod and Peterson 2001; Schindler and Parker 2002; Cambray 2003; Knapp 2005).

The figures in Table 5 do not include organisms native to other parts of the province that have been moved to areas where they did not exist previously. Such movement of vertebrates has caused severe problems in the Queen Charlotte Islands where introduced mainland species are causing ecological damage. Rats (*Rattus* spp.) and raccoons (*Procyon lotor*), the latter introduced from mainland BC in the 1940s to promote fur trapping, are a serious threat to populations of nesting marine birds (Harfenist and Kaiser 1997; Hartman et al. 1997). Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) were introduced to the Queen Charlotte Islands for hunting around 1900 (Foster 1989). In the absence of predators, they have multiplied to the point where their heavy browsing on several tree species has altered local plant communities (Pojar et al. 1980; Pojar 1999).

Table 5. Number of alien species established in coastal British Columbia (vertebrates and vascular plants) and recorded in the Strait of Georgia (marine and estuarine species).

Coastal British Columbia	Number of established introductions
Vertebrates[a]	
Freshwater fish	12
Amphibians	2
Reptiles	2
Birds	14
Mammals	11
Total vertebrates	41
Vascular plants[b]	–
Species occurring frequently	406
Species occurring rarely	223
Total Plants	629

Strait of Georgia Strait only[c]	Number of recorded introductions
Seaweed	5
Plants	18
Hydroids, Anemones (Cnidaria)	2
Worms (Polychaeta)	7
Snails, Slugs (Gastropoda)	8
Shellfish (Bivalvia)	11
Amphipods, Isopods (Crustacea)	6
Sea squirts (Tunicata)	4
Sponges (Porifera)	2
Finfish	5
Birds	2
Mammals	1
Other (Kamptozoa, Foraminifera, Platyhelminthes)	2
Total species	73

Sources: [a] Animal data (current to 2004): CDC. [b] Plant data (various dates): Ceska 1997; Douglas et al. 1998-2002; Klinkenberg 2004; UBC Herbarium Database; Roy Cranston, pers. comm. [c] Marine/estuarine data (current to 1999-2000): Levings et al. 2002.

Note: Atlantic salmon and American shad, both anadromous species, are counted twice: as "freshwater fish" under Coastal BC and as "finfish" under Strait of Georgia. Alien Coastal BC mammals includes feral cats and horses, but not other domesticated animals.

GREEN INVADERS: THREE NOTORIOUS PLANT SPECIES IN COASTAL BC

Scotch broom (*Cytisus scoparius*), considered one of the five most destructive alien plants in Canada (Mosquin and Whiting 1992), was introduced intentionally as an ornamental in 1850 to southern Vancouver Island. It has since spread along the east side of Vancouver Island, across the Gulf Islands, and into the Lower Mainland and Fraser Valley. Broom thrives on disturbed sites on poor soils, such as along rights-of-way, roadsides, and in new forestry sites (Prasad 2000). It lacks natural enemies, tolerates drought and cold, and produces many seeds that can lie dormant for decades (Peterson and Prasad 1998).

Purple loosestrife (*Lythrum salicaria*) was brought to North American 200 years ago. It was transported to Vancouver Island by the early 1900s and then spread to much of the Georgia Basin and Fraser Valley. Grown as a garden ornamental until the 1980s, it also spread along roadside ditches. Loosestrife outcompetes native vegetation in riparian and wetland habitats (Mal et al. 1992), altering ecosystem productivity and function (Grout et al. 1997) and displacing wetland animals and fishes, few of which feed on, or otherwise use, purple loosestrife (White and Haber 1992).

Cordgrasses (*Spartina* spp.) are salt-tolerant plants, native to the Atlantic coast. They were intentionally introduced to the Pacific Northwest to create duck habitat and stabilize shorelines. Aggressive eradication efforts are now being undertaken to halt their invasion of the Fraser delta (Williams 2004) because cordgrasses replace native vegetation in mudflats and marshes (Simenstad and Thom 1995). This increases the build-up of sediments (Thompson 1991) and causes declines in both benthic organisms (Gray et al. 1991) and bird habitat (Foss 1992).

The numbers of alien species reported here are only from some of the better known groups of organisms and are not the total number established in coastal BC. Alien microorganisms, insects, and other invertebrates are not well documented but are likely abundant. For example, ballast water in cargo ships may contain thousands of tiny organisms, including algae and zooplankton, in each cubic metre of water (Levings et al. 1998). More than 3000 species of animals and plants are estimated to be transported around the world daily in ballast water (NRC 1996); some, such as zebra mussels in the Great Lakes system, have had devastating impacts.

With respect to insects, Smith (1994) identified more than 300 alien insect species in British Columbia. Some are serious economic pests and others were introduced intentionally as part of biological control programs for pests. More comprehensive monitoring would likely find more species, especially among classes of organisms that are hard to find or identify as aliens.

Aliens from Neighbouring Jurisdictions

Some alien species reach BC under their own locomotion after being intentionally or accidentally released in neighbouring jurisdictions. Lower Mainland populations of opossum (*Didelphus virginiana*) may be descendants of opossums intentionally introduced to Washington State in the 1920s (Nagorsen 1996). European green crab (*Carcinus maenas*) is rapidly expanding its range along the coast. It was first found along the coast of California in 1989, Oregon in 1997, Washington in 1998, and west Vancouver Island in 1999 (DFO 1999). Since then, green crabs have been found along the west side of Vancouver Island from Esquimalt Harbour to Port Eliza (Kieser 2004). It is a voracious predator on invertebrates and, because it shreds eelgrass, is the leading cause of declining eelgrass beds in Nova Scotia (Garbary et al. 2004). It is feared that it could damage Dungeness crab and shellfish fisheries, and reduce the food supply for shorebirds and other species (Jamieson et al. 1998).

Twenty-four non-native species (all but one are invertebrates) reported as established in Puget Sound are not found in the shared waters of the Strait of Georgia (Cohen 2004); all are potential invaders north along the BC coast.

Valuable Aliens

Although they carry potential (or realized) costs to ecosystems and to native commercial species, lucrative industries have sprung up around some coastal aliens. Alien marine invertebrates account for 58% (40 species) of the non-native species in waters of the Strait of Georgia (Table 5). Among these are commercially valuable mussels, oysters, scallops, and clams. The Manila clam (*Tapes philippinarum*), unintentionally introduced in the 1930s, has colonized much of the province's south coast where it apparently co-exists with native clams (DFO 2001; BCSGA 2004) and supports a commercial clam industry valued at $7.6 million in 2003 (DFO 2004). The introduction of Atlantic salmon aquaculture to the BC coast has simultaneously fuelled an industry worth $250 million annually (BCMAL 2003) and controversy over threats to wild salmon fisheries from this alien species and the net-pen rearing methods (e.g., Senate Standing Committee on Fisheries 2001).

WATCHING THE BORDERS: ECONOMICALLY DESTRUCTIVE SPECIES

The Canadian Food Inspection Agency regulates and inspects plant products that could bring alien species into Canada. Provincial governments and industries also have monitoring and eradication programs aimed at keeping out alien species. Some of the economically costly invaders BC is working to keep out include:

- **European and Asian gypsy moths** (both *Lymantria dispar*) threaten the province's forestry, agriculture, and nursery sectors as well as the native Garry oak forests (Agriculture Canada 1986; Humble and Stewart 1994). If the moths become established, expensive quarantines and export embargoes will be needed. Because the European gypsy moth is widely established in eastern North America, constant monitoring and inspections are required to prevent them from becoming established in BC. A network of gypsy moth traps is monitored every year in BC by the Canadian Food Inspection Agency to give early warning of new gypsy moth introductions. Monitoring and eradication costs up to $1 million annually, depending on whether treatments are required to prevent them from becoming established (Forest Practices Branch, BC Ministry of Forests).

- **Sudden oak death** (*Phytophthora ramorum*) is a fungus that threatens both the forestry and horticulture sectors. It can infect, and in some cases kill, many plant species that are found on the west coast, including Garry oak, arbutus, manzanita, big leaf maple, alder, salmonberry, Douglas-fir, and a variety of nursery species, such as rhododendron and camellia (BCMAFF 2004; CFIA 2005). Sudden oak death has entered BC twice in recent years, resulting in the imposition of quarantines on imports of nursery stock as well as lost sales and regulatory costs (Allen et al. 2003; CFIA 2005). Although BC is currently free of sudden oak death, the presence of this pathogen elsewhere in the world has resulted in an estimated national economic impact within Canada approaching $1 million (Allen et al. 2003).

- **Ballast water organisms**: Many alien species in both Strait of Georgia and Puget Sound arrived in ballast water or on hulls of ships (Levings et al. 1998, 2004; Cohen 2004). To reduce the risk of foreign introductions, the Vancouver Port Authority, as of 1997, requires most ships arriving in port to exchange ballast water in mid-ocean, rather than in port (VPA 2002). This is not a complete solution as some coastal organisms may remain in ballast water in Vancouver (Levings et al. 2004) and ships travelling from other Canadian and American ports along the west coast do not have to abide by the mid-ocean exchange regulation. With more technological development, treating ballast water with ultra-violet radiation may become an alternative to mid-ocean exchange.

5. Secondary Indicator: Change in area of sensitive ecosystems on eastern Vancouver Island and the Gulf Islands

This is a status indicator. It addresses the question: What is the current condition of key natural ecosystems in BC?

In 1993, Environment Canada, the BC government, and other partners began the Sensitive Ecosystems Inventory, a project to classify, identify, and map ecosystems that were considered rare or particularly fragile on eastern Vancouver Island and the Gulf Islands. McPhee et al. (2000) emphasize the value of these "sensitive" ecosystems to coastal biodiversity because they are:

- rare, either naturally or because of human activities, and often occur in conjunction with rare species of animals and plants;
- specialized, providing unique habitats that are often in low supply;
- small and occur within a mix of different ecosystem types, resulting in a general association with high numbers of species and individuals.

Sensitive ecosystems may be fragile when they occur in small patches, even if relatively common, or they may be sensitive to forces of disturbance, such as land development, invasive species, and climate change. This indicator shows the trend in the area of sensitive ecosystems in a populated region of BC.

Methodology and Data

Work focused on a 412,000-ha study area stretching from just north of Campbell River south to Sooke and including the Gulf Islands (Figure 4). Seven sensitive ecosystems and two human-modified ecosystems were mapped; these initially occupied 7.9% and 11.6% of this study area, respectively (Table 6). The two modified ecosystems were included because of their value to wildlife and for biodiversity in general (McPhee et al. 2000).

Specific details about inventory methods are available in Ward et al. (1998). Data were collected from air photos (taken 1984–1992, with most from 1992), most of which were at a scale of 1:10,000 or 1:15,000. Nearly 7400 sites were identified from these photos; 30% of the sites were visited to check the accuracy of photo interpretations. A Geographic Information System was used to construct 66 maps. Changes in the area of the ecosystems mapped from 1992 air photos were determined by overlaying the mapped sensitive ecosystems on recent 2002 photos. Changes were documented as the total area disturbed or lost (Axys 2005).

Disturbance was classified into types, including agricultural, cleared/logged, industrial (e.g., gravel pits, dams, fish farms), rural use, trails/recreational, urban use, and "other." Not all types of disturbance could be identified (notably invasive species).

Figure 4. Study area for sensitive ecosystem inventory and mapping project.
Sensitive ecosystems occupied 7.9% of the study area in 1992.

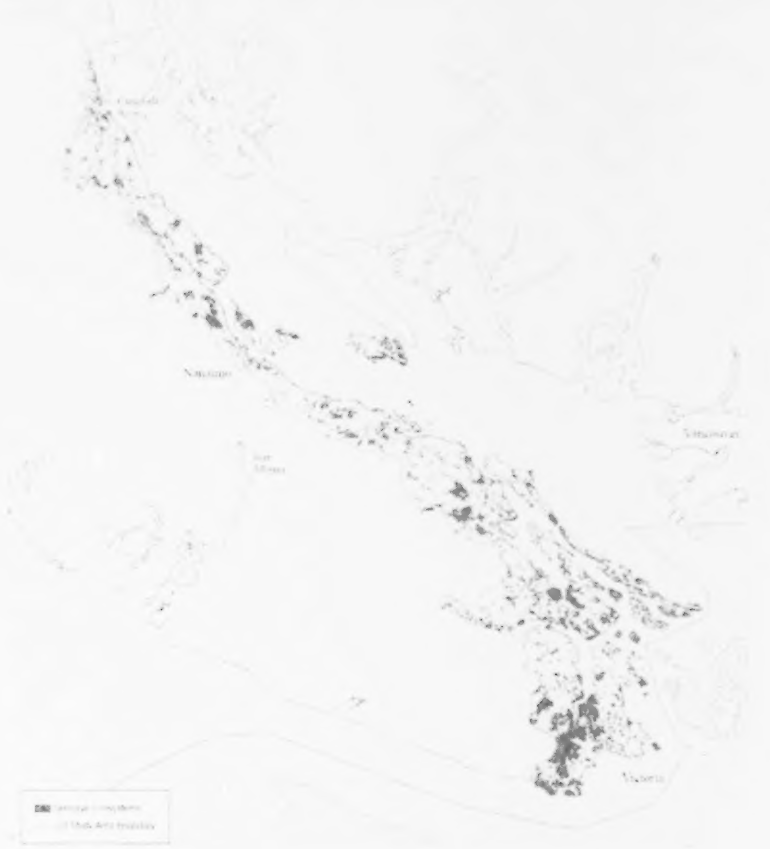


Table 6 lists the seven types of sensitive ecosystems and shows the net change in the area of each type in the study area between 1992 and 2002. The table also shows the changes in area of two types of human-modified ecosystems that have important values for wildlife: seasonally flooded agricultural field and older second-growth forest (i.e., 60–100 years old). The remaining, unclassified land in the study area was made up of modified urban or rural lands and recently logged forest (i.e., younger than 60 years).

One of the modified ecosystems, older second-growth forest, occupied more area than any other ecosystem. The sensitive ecosystems with the greatest extent were older forest (older than 100 years), followed by wetland and riparian ecosystems. The ecosystem with the smallest total area was the sparsely vegetated type, with only 326 hectares in 1992, or one-third of a square kilometre.

Table 6. Change in the area of seven types of sensitive ecosystems and two human modified ecosystems on eastern Vancouver Island and the Gulf Islands between 1992 and 2002.

Ecosystem	Description	1992 area (ha)	2002 area (ha)	Loss (ha)	% Loss
Sensitive ecosystems					
Coastal bluff	Vegetated rocky islets, shorelines, and coastal cliffs	1,042.9	1,041.7	1.2	0.1
Terrestrial herbaceous	Mosaics of coastal grassland meadows and moss-covered rock outcrops	4,242.9	4,218.5	24.4	0.6
Older forest	Forests older than 100 years	10,613.8	9,698.4	915.4	8.6
Riparian	Vegetated floodplains, stream and lakeshores, and gullies	6,712.3	6,401.5	310.8	4.6
Sparsely vegetated	Dunes, spits, and inland cliffs	325.6	321.1	4.5	1.4
Woodland	Open forests dominated by deciduous trees with canopy cover generally less than 50%	2,518.7	2,452.6	66.1	2.6
Wetland	Marshes, fens, bogs, swamps, shallow water, and wet meadows	7,053.9	6,912.1	141.8	2.0
Total		32,510.1	31,045.9	1,464.2	4.5
Modified ecosystems of importance to wildlife					
Seasonally flooded agricultural field	Agricultural fields flooded in winter for use by migratory birds	2,778.6	2,763.3	15.3	0.5
Older second growth forest	Large stands of conifers 60–100 years old	44,890.6	37,527.5	7,363.1	16.4
Total		47,669.2	40,293.9	7,378.4	15.5
Total sensitive and modified ecosystems					
		80,179.3	71,342.6	8,836.7	11.0

Source: Axys 2005.

Interpretation

Nearly 1500 hectares of sensitive ecosystems on the east coast of Vancouver Island and the Gulf Islands were disturbed or lost between 1992 and 2002 (Table 6). Most of the loss was due to logging and clearing. Older forests, which are favoured by many wildlife species for their structural complexity, were hardest hit, losing 8.6% of their area. Riparian ecosystems were reduced in area by 4.6%. This is a concern because these areas support disproportionately high numbers of species per unit area and provide travel corridors for some species (McPhee et al. 2000). Woodlands lost 2.6% of their area, and wetland, sparsely vegetated, terrestrial herbaceous, and coastal bluff ecosystems each lost less than 2%. The rate of loss of sensitive ecosystems on eastern Vancouver Island and the Gulf Islands averaged almost 150 hectares per year. The remaining area of sensitive ecosystems in the study area in 2002 was just over 31,000 hectares.

The main type of disturbance for ecosystems in the study was "cleared/logged," which removed a total of 1176 hectares of sensitive ecosystems, as well as 6833 hectares of older second-growth forest (Axys 2005). About 16% of older second-growth forest was disturbed or lost in the 10-year period. Such older second-growth forest can support a broad range of wildlife species depending on stand size, vegetation structure, and connectivity (McPhee et al. 2000). These maturing forests are also important because they will eventually become older forest. Most of the recent harvest of second-growth forest has taken place in low-elevation stands near Nanaimo and Comox (McPhee et al. 2000; Axys 2005). The fact that there has been rapid urban growth in the Nanaimo Regional District during the early 1990s suggests that at least part of the land was cleared for conversion to other uses, such as rural subdivision (RDN 2003). Such total conversion of forested land has more serious impacts on biodiversity than logging for continued forestry, because converted habitat is essentially lost forever.

The loss of sensitive ecosystems on eastern Vancouver Island is not an isolated example. Wetlands in the Lower Mainland now cover only 10% of the area they once did (Boyle et al. 1997). Many were drained and converted into agricultural land in the early 1900s. Between 1986 and 1993, 435 hectares of wetlands were also lost in the Greater Vancouver Regional District (BCMSRM 2004). Farther north, along the central and northern coasts of BC, industrial forestry has reduced the amount of old forest in high productivity ecosystems to a level that is "much lower" than would be expected from natural disturbance (Holt and Sutherland 2003, 2004).

Supplementary Information: Two Sensitive Marine Ecosystems in Coastal BC

Kelp forests and eelgrass meadows are two vital marine ecosystems on the Coast. They provide intertidal and subtidal habitat for many invertebrates, fish, birds, and mammals, as well as for plants that cling to seaweed fronds. Herring, a key forage fish for other species, spawn their eggs directly onto eelgrasses, and several other fish species use eelgrass meadows as nurseries (Butler 2003). Eelgrass and kelp ecosystems cover 13%

and 29% of the total BC coastline, respectively (based on 1995–2001 air photos; Corporate Information Services, Ministry of Agriculture and Lands 2005).

Both eelgrass and kelp occur close to shore and are therefore particularly sensitive to impacts from human activities on land and along the shoreline. These activities include discharge of pollution that reaches marine waters, construction activities for docks and other shoreline structures, and coastal dredging. Other threats include global climate change (rising temperature and sea levels) and invasive species such as the European green crab, which destroys eelgrass shoots (Garbary et al. 2004).

Several mapping and monitoring projects to assess the health and extent of these ecosystems are in progress (e.g., Wright 2002; Dunster 2003).

6. Key Indicator: Progress toward completing recovery strategies for species at risk in BC

This is a response indicator. It addresses the question: What is being done to protect threatened species and biodiversity? The indicator shows the progress being made in one type of societal response to the issue of threatened species—the development of species recovery strategies.

As signatory to the 1996 Accord for the Protection of Species at Risk, British Columbia is committed to action that will enable threatened and endangered species to recover. Recovery planning for species listed as extirpated, endangered, or threatened involves the collaboration of government, industry, academia, and individuals. Planning involves preparing two documents: a recovery strategy and a recovery action plan (see text box). Because is it unlikely that species would recover without human intervention, tracking the listed species that have recovery strategies and action plans is one measure of societal effort and commitment toward species recovery. Taylor et al. (2005) recently demonstrated that in the United States, the status of species that had a dedicated action plan for at least two years was more likely to improve than for species without recovery plans.

This indicator measures progress in preparing recovery strategies for species that have been assessed by COSEWIC as extirpated, endangered, or threatened. The timeline for completion of recovery strategies is one year for endangered species and two years for threatened species. A management plan, which has less stringent content and format requirement, is required within three years of listing for species designated as special concern. This indicator reports only the status of recovery strategies; there was insufficient information to report on the current status of action plans. The indicator does provides an indirect measure of recovery action, however, because most recovery teams actively engage in implementation of recovery action even before the strategy is complete.

RECOVERY PLANNING

Recovery planning in Canada involves preparation of two types of documents:

- Recovery strategy: Details the information known about a species, its habitat, and threats to its survival. The document also outlines objectives and identifies additional information on species status and different recovery approaches that will help teams plan the recovery of the species.
- Recovery action plan: Includes specific projects or activities needed to meet the objectives outlined in the recovery strategy. The plan evaluates the socio-economic costs and benefits of improving the species' status.

An action plan together with a recovery strategy is often called a "recovery plan."

Methodology and Data

This indicator focuses on coastal BC species at risk as listed federally by COSEWIC. Each species underwent a formal status assessment as a prerequisite for COSEWIC listing. Data on the progress of recovery strategies are compiled and tracked by the Biodiversity Branch, BC Ministry of Environment. The BC Ministry of Environment is the lead agency on recovery strategies for many BC terrestrial species and it is a co-leading agency for recovery teams working on freshwater fish and molluscs. The Canadian Wildlife Service is responsible for recovery strategies for migratory birds, and Fisheries and Oceans Canada is responsible for many marine mammals, fish, and invertebrate species; it also co-leads the recovery teams for freshwater fish and molluscs.

For COSEWIC data, the term "species" also includes subspecies and even specific populations of a single species where COSEWIC has deemed it necessary to rank these separately. For example, two subspecies of peregrine falcon, the *anatum* and *pealei* subspecies, are counted separately in the dataset. Four populations of Pacific killer whales are also recognized. There is not necessarily a one-to-one relationship between COSEWIC-listed species and recovery strategies because recovery strategies may include multiple subspecies or populations, or even multiple species that inhabit the same ecological region (e.g., the Garry oak ecosystem).

Interpretation

Recovery strategies for extirpated, endangered, or threatened species are in progress across the full range of taxonomic groups and political jurisdictions (Table 7). Strategies have been started for 86% of species and 26% have been completed and are under review. Recovery planning in general appears to be in mid-process: as of 2005, no strategies had been approved and published.

Although writing and implementing a recovery plan does not guarantee improvement in the status of a species, it is a necessary step toward coordinating a recovery effort that has the greatest possible chance of being successful (Taylor et al. 2005). In addition to producing a plan, the process of recovery planning may produce interim recovery measures. There are also less obvious benefits from regularly bringing together species experts, interest groups, industry representatives, and others to discuss the welfare of a species at risk. Most recovery teams are also involved in implementing recovery actions, even before completing the recovery strategy or action plan.

Table 7. Progress, by taxonomic group, on development of recovery strategies for west coast species listed by COSEWIC as extirpated, endangered, and threatened.

Taxonomic group	No. listed species	Not yet started	In process	Draft in review[a]
Amphibians	2	–	1	1
Arthropods	5	1	4	–
Birds	7	2	2	3
Fishes, freshwater	12	1	3	8
Fishes, marine	5	2	3	–
Lichens	1	–	1	–
Mammals, marine	9	2	5	2
Mammals, terrestrial	4	–	3	1
Molluscs, aquatic	2	–	1	1
Molluscs, terrestrial	3	–	–	3
Mosses	3	–	3	–
Reptiles	4	–	2	2
Vascular plants	29	4	24	1
Total	86 (100%)	12 (14%)	52 (60%)	22 (26%)

Sources: Species status: COSEWIC website: *www.cosewic.gc.ca/eng/sct5/index_e.cfm*. Progress in recovery: Biodiversity Branch, BC Ministry of Environment.

[a] This category includes strategies for which there is an update in progress.

Notes: Data as of May 2005. Species listed as "special concern" by COSEWIC are excluded because they do not require recovery strategies. No recovery strategies have yet been published.

Notes from informal discussions with recovery teams show that action plans are in preparation for many listed species. Although there is still some breadth of opinion as to how recovery actions will be implemented, there appears to be a growing consensus that multi-species or ecosystem-level action plans are desirable, even if recovery strategies themselves may be species-specific. Action plans that already exist for certain species, because they were part of previous processes, include:

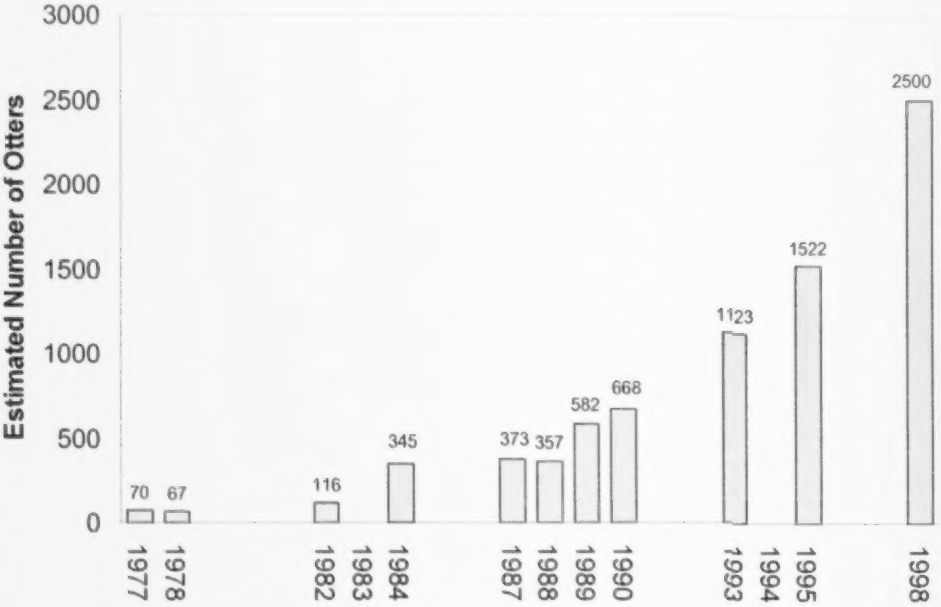
- Marbled murrelet (*Brachyramphus marmoratus*)—a small seabird that requires old-growth coastal forests for nesting. An action plan was developed in 1993 (Kaiser et al. 1994) and recovery efforts continue.
- Peregrine falcon (*Falco peregrinus*, ssp. *anatum*)—threatened by habitat loss and small population size (Environment Canada 2004). An action plan was first developed in 1987 (Erickson et al. 1988). Initial goals have been met and an update is under way.
- Vancouver Island marmot (*Marmota vancouverensis*)—lives exclusively in alpine and subalpine habitats on a few Vancouver Island mountains. The first action plan was written in 1994; it was reassessed in 2000. Recovery efforts include research, monitoring, captive breeding, and reintroduction to the wild (Vancouver Island Marmot Recovery Team 2000).

As older plans, such as these, are revised they will better meet the requirements of SARA Action Plans. Recovery efforts for some species are initiated before recovery planning is completed, or even before the species is listed by COSEWIC. For example, a purple martin nest box program initiated in 1986 has increased the population of this swallow in BC from fewer than 10 to more than 300 pairs (GBEARS 2004).

Supplementary Information: Recovery of the Sea Otter

The sea otter has the distinction of being one of the few Canadian species to be re-introduced after extirpation. Historically 150,000–300,000 sea otter ranged the Pacific Rim, from northern Japan to Baja California (Watson et al. 1997). By 1900, fewer than 2000 animals remained as a result of a global interest in sea otter fur. The sea otter was extirpated from BC by 1929 (Kenyon 1969). Between 1969 and 1972, 89 Alaskan otters were reintroduced to northwest Vancouver Island (Watson et al. 1997). Sea otter populations have since increased from 70 animals in 1977 to more than 2500 animals in 1998 (Figure 5). Approximately 80% of these animals occur on the west coast of Vancouver Island, with remainder along the BC central coast (Watson 2000). Sea otter numbers continue to increase and in some areas the population is likely at equilibrium (J. Watson, pers. comm.), meaning it has reached a state where numbers remain fairly steady.

Figure 5. Total number of sea otters from surveys of seven otter populations on the BC coast, 1977 to 1998.



Source: 1977–1995 data from Watson et al. 1997; 1998 data from Watson 2000.

Notes: Data are absent for years where conditions did not permit surveys of all seven groups. The count in 1995, although included in the indicator, was considered incomplete for one of the seven otter groups.

Originally listed as endangered in 1978, the sea otter status was revised in 1996 to threatened, a status it retains under SARA (Sea Otter Recovery Team 2003). The relatively small population remains vulnerable to catastrophes such as oil spills, the single biggest threat (Watson et al. 1997; Sea Otter Recovery Team 2003). Other potential threats include disease and parasites, low genetic diversity, marine biotoxins, contaminants, entanglement in fishing gear, collisions with vessels, illegal kills, and human disturbance (Sea Otter Recovery Team 2003). In 2002, Fisheries and Oceans Canada took the lead in developing a new national recovery strategy for sea otters in Canada consistent with the requirements of the federal Species at Risk Act (Sea Otter Recovery Team 2003). The next COSEWIC status report on sea otters is due in 2006.

Sea otters are a keystone species: their reintroduction had a profound effect on recovering nearshore communities of species in BC (Sea Otter Recovery Team 2003). Sea otter predation reduces the abundance, size, and distribution of invertebrate prey species, including sea urchins. In the absence of otters, the urchins dominate the rocky nearshore and graze kelp. Where sea otters are present, sea urchin biomass decreases, often dramatically. This relieves pressure from sea urchins grazing on local kelp and increases the abundance of kelp forest (Estes and Duggins 1995). Kelp forests provide important habitat for many organisms by dampening wave surges, shading the sea floor, and adding structure above the benthic boundary (Steneck et al. 2002).

A particularly interesting twist in recovery of the sea otter comes from its position in the marine food chain, sandwiched between two other species at risk. Sea otters feed on one threatened species, the northern abalone (*Haliotis kamtschatkana*), and they may be fed upon by a second, the killer whale (*Orcinus orca*), both of which are federally designated as at risk. Where otters are present, northern abalone occur at low but stable densities in crevices that provide refuge from predation (Watson 2000).The removal of the sea otter from the BC coast allowed an artificial increase in the biomass of northern abalone, creating the basis for lucrative commercial and recreational fisheries (Estes and VanBlaricom 1985; Watson and Smith 1996). The recent collapse of many abalone fisheries along the west coast has created controversy over the sea otter's recolonization of its historic range (Estes and VanBlaricom 1985; Wendell et al. 1986; Estes 1990; Wendell 1994; Watson and Smith 1996). The collapse of abalone fisheries in BC is unlikely to be solely because of sea otter predation (Sloan and Breen 1988; Davis et al. 1996), but it is difficult to distinguish the effects of otter predation from those of human harvesting.

Although killer whale predation has not been extensively documented in BC, information from southwestern Alaska suggests that the whales may have a profound effect on sea otter numbers. The Alaskan otter population declined by 75% from 1965 to 2000 (Doroff et al. 2003), a change attributed to predation by killer whales (Estes et al. 1998).

WHAT IS HAPPENING TO COASTAL BIODIVERSITY?

Indications are that biodiversity on the BC coast appears to be declining, particularly in the most populated areas of the south coast. Biodiversity in BC is also poorly understood, as it is globally. The international Convention on Biological Diversity, of which Canada is a signatory, identified an urgent need worldwide to develop a basic understanding of biodiversity as a basis for implementing effective conservation measures (UNEP 1992). For most coastal organisms in BC, fundamental information, such as provincial distribution, is incomplete or nonexistent, which makes it difficult to form conclusions about the status of much of the province's biodiversity. The status of only a small number of species is regularly monitored, and the state of knowledge of communities and ecosystems is even less complete than the understanding of single species. Given this state of knowledge, it is hard to define meaningful indicators of biodiversity, and most of the existing indicators of the overall state of biodiversity in BC are not well validated. Indicators used in this report are an advance on previous reporting, but still represent a compromise between ideal indicators and those for which data are currently available.

Summary of results from the indicators show the following:

- The status of coastal vertebrates as a group has declined over the past 14 years, as shown by an increase from 18 to 22 red-listed species of coastal vertebrates in the conservation status indicator. In addition to the appearance of new species on the red list, there has been no real improvement in status for most threatened and endangered coastal vertebrates that were on the red list in 1992.

- After 20 years of increasing population size, killer whales were added to the provincial and federal lists of species at risk after entering a period of population decline.
- More than 600 species of alien plants have become established on the BC coast; some of these have become formidable invaders. At least 41 species of alien vertebrates and 44 species of invertebrates have been introduced. Left uncontrolled, some alien species could have large negative impacts on coastal ecosystems and some commercial industries.
- Despite the relatively small areas they occupy, the rare and sensitive ecosystems of eastern Vancouver Island lost 5% of their area (1464 ha) over the past 10 years. At this rate, they could be gone in 20 years. Two human-modified ecosystems (seasonally flooded agricultural fields and older second-growth forest), both of which offer value to wildlife, were lost at three times this rate.

In terms of societal response to these changes, species recovery began for many species along coastal BC before the Species at Risk Act was proclaimed. Federal accords and legislation around species at risk have instigated the development of recovery strategies for more than 80% of the COSEWIC-listed species in the province. As necessary as species recovery programs may be, they are generally reactive, occurring once a species has declined to the point of near endangerment. Recovery is also generally slow and very expensive: in the time it takes to improve the status of one species, several more may become at risk. Of the 21 known species that have become extinct or extirpated from the province in recent history, 15 used to occur on the BC coast (BCMELP 2000). Only one of these—the sea otter—has since been successfully reintroduced. Although the story of the sea otter is a positive one, during the time of its recovery, an additional 15 species observed historically on the coast apparently disappeared. These species, which include 12 plants and 3 mammals, have not been seen anywhere in the province for more than 20 years (BCMELP 2000).

WHY IS IT HAPPENING?

Coastal ecosystems are uniquely characterized by a union of freshwater, saltwater, and terrestrial realms, and the intermingling of a wide variety of life forms that exploit the rich resources that result. Most British Columbians live on the coast, however, and the human population and activity is placing stress on the natural environment from transportation, industry, resource harvest, urbanization, and agricultural development. The combination of these numerous pressures can perturb natural ecosystems to the point where local populations are extirpated and natural processes are impaired (e.g., Solan et al. 2004).

Steep elevation gradients, abrupt changes in habitats, and high levels of productivity on the coast result in a large number of organisms and species occupying a relatively small amount of space. The coastal landscape is naturally fragmented into small pieces by islands, inlets, bays, and peninsulas. Over time, geographically separated populations have produced unique local ecotypes, varieties, and subspecies. Although many of BC's ecosystems are relatively intact, ecosystem loss is greatest in the province's southwest corner along its coast. The southwest coast formerly contained some of the highest levels of biodiversity in the province; however, it has been severely altered ecologically and is now characterized by a regional concentration of threatened and endangered species and subspecies, and extirpated populations (BCMWLAP 2002). Biodiversity on the coast is particularly susceptible to human pressures and even localized development can have disproportionate effects on locally unique taxa.

It is not just the growing human population on the coast that is putting pressure on BC's coastal biodiversity. Global climate change is likely to become the greatest threat to biodiversity in many regions of the world, resulting in severe impacts and extinctions as it compounds the impact from local threats (Thomas et al. 2004). Climate change has the potential to increase the frequency and extent of disturbance, such as fire and insect outbreaks (McKenzie et al. 2004), to create favourable conditions for invasive species, and to produce ecological shifts that may occur faster than species can adapt (Opdam and Wascher 2004). Although it is not possible to predict how much climate change will affect biodiversity on the BC coast, it is likely that it will create additional pressure in ecosystems that are already stressed in many ways.

WHY IS IT IMPORTANT?

From a purely human standpoint, the ecological processes maintained by biodiversity provide a host of "ecosystem services" upon which humanity is entirely dependent.

Although ecosystem services provide life support for the planet, their value is poorly understood, rarely articulated, and generally ignored in decision-making (Emerton and Bos 2004). In one analysis of the value of ecosystem services in BC's lower Fraser Valley, the authors conclude that protecting this ecosystem may save society hundreds of millions of dollars every year (Olewiler 2004).

Biodiversity is an essential component of four main categories of ecosystem services (e.g., MEA 2005a):

- Providing food, water, timber, and fibre. In 2004, agriculture, forestry, fishing, and hunting accounted for more than $4.9 billion of BC's gross domestic product (BC Stats. 2005);
- Regulating climate, floods, disease, water quality, and waste treatment. Regulating services have been systematically undervalued even though they are irreplaceable;
- Supporting ecosystem functions, such as soil formation, pollination, and nutrient cycling; and
- Supporting cultural activities, such as recreation, aesthetic enjoyment, and spiritual fulfilment.

In terms of the contribution of biodiversity to ecosystem services, research shows that the composition and richness of ecosystems may be dramatically changed by the loss of just one species (e.g., Paine 1974). Also, the order in which species are lost from an ecosystem appears to influence ecosystem integrity. Loss of certain key species leads to rapid, systematic loss of others (Raffaelli 2004), and can result in reduced ecosystem function and stability because surviving species may not adequately replace the function of those lost (Solan et al. 2004). A damaged ecosystem becomes increasingly vulnerable to threats that it may formerly have been able to resist, such as invasive plants (Zavaleta and Hulvey 2004).

Globally, human use of all ecosystem services is growing rapidly, and yet recent research shows that approximately 60% of the Earth's ecosystem services are being degraded or used unsustainably (MEA 2005a). In marine coastal ecosystems, these ecosystem processes are of global importance to climate, nutrient budgets, and primary productivity (Field et al. 1998), but can be compromised by human-induced stresses (Vitousek et al. 1997). The continued provision of ecosystem services relies on healthy ecosystems, of which biodiversity is a major and vulnerable part (MEA 2005b).

WHAT IS BEING DONE ABOUT IT?

Biodiversity is affected by many areas of policy because it is directly and indirectly influenced by a variety of pressures from human activity, including industrial processes, land conversion, forestry, fishing and other harvesting, agriculture, environmental contamination, and climate change. Because it is not possible to describe all policies that affect the pressures on biodiversity, the following summary focuses on initiatives most relevant to coastal biodiversity.

Key Federal Initiatives

- UN Convention on Biological Diversity (CBD): In 1992, Canada, with support from provincial and territorial governments, was the first industrialized nation to sign this convention. The main objective of the CDB is to achieve, by 2010, a significant reduction in the current rate of loss of biodiversity at the global, national, and regional level. The Canadian Biodiversity Strategy, published in 1996, is intended to guide implementation of the CBD in Canada. (*www.biodiv.org/default.shtml*)
- Species at risk agreements and legislation: In 1996, British Columbia and all other Canadian jurisdictions endorsed the Accord for the Protection of Species at Risk that commits the provinces and territories to work with the federal government to protect and recover species at risk. The federal Species at Risk Act (SARA), which came into force in June 2004, is the federal government's legislative response to the Accord. SARA is intended to prevent Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct; to provide for the recovery of endangered or threatened species; and to encourage the management of other species to prevent them from becoming at risk. SARA has prompted recovery planning for species at risk all across the country. British Columbia and the federal government

have endorsed a bilateral agreement to work cooperatively on the implementation of SARA. (*www.sararegistry.gc.ca/*)

- Committee on the Status of Endangered Wildlife in Canada: COSEWIC is an independent body of experts who use scientific, aboriginal, and community knowledge to classify species in Canada as extirpated, endangered, threatened, of special concern, data deficient, or not at risk. COSEWIC includes representation from British Columbia. Under the Species at Risk Act, the government of Canada will take COSEWIC's recommendations into consideration when establishing the legal list of species at risk. (*www.cosewic.gc.ca/index.htm*)
- Invasive Alien Species Strategy for Canada: British Columbia was a participant in this strategy, which was published in 2004, to address the threat of invasive species to Canada's wildlife, forests, fisheries, and other resource sectors. It prioritizes key actions and identifies the need for action plans on aquatic invaders, invasive plants, and introduced terrestrial animals. (*www.cbin.ec.gc.ca/primers/ias_invasives.cfm*)
- Canada's Oceans Strategy: Announced in 2002, the strategy is based on the principles of sustainable development, integrated management, and the precautionary approach. Its main objectives are understanding and protecting the marine environment, supporting sustainable economic development, and providing international leadership and oceans governance. It involves collaboration between the federal government, provinces, First Nations, oceans industries, academia, and the general public, as well as with other nations. In 2004, the federal and provincial governments signed a Memorandum of Understanding Respecting the Implementation of Canada's Oceans Strategy on the Pacific Coast of Canada to formalize the commitment of both governments to achieve the objectives. (*www.cos-soc.gc.ca/dir/cos-soc_e.asp*)

Key Provincial Government Initiatives

- BC Conservation Data Centre: The CDC systematically collects and disseminates information on plants, animals, and ecosystems (ecological communities) at risk in British Columbia. This information is compiled and maintained in a computerized database that provides a centralized and scientific source of information on the status, locations, and level of protection of these organisms and ecosystems. (*www.env.gov.bc.ca/cdc/*)
- Strategic land use planning: Strategic land use plans, which include identifying key areas for management and conservation of biodiversity, are under way and at various stages of completion in five coastal areas, including the central coast, the north coast, the Queen Charlotte Islands, Vancouver Island, and the Sea-to-Sky Highway. (*ilmbwww.gov.bc.ca/ilmb/lup/*)
- Revisions to the Wildlife Act: In 2004, this act was amended to allow cabinet to designate the full range of species provided for in the federal Species at Risk Act, including plants and invertebrates at risk. The Wildlife Act regulates wildlife harvest, establishes wildlife management areas and critical wildlife areas, and designates endangered species.

- Species at risk under the Forest and Range Practices Act: In 2004, the Minister of Environment identified 39 species, all previously listed by COSEWIC, as Species at Risk under this act. These species now require a greater level of consideration when planning forestry and range activities.

Other Initiatives

There are many other initiatives by international bodies, municipal governments, community groups, and volunteers.

- Georgia Strait Alliance was originally formed in 1990 by concerned citizens with the purpose of protecting and restoring the marine environment and promoting the sustainability of the Strait of Georgia and its adjoining waters and communities. The GSA has several program areas including marine protected areas, clean air and water, and intertidal stewardship. (*www.georgiastrait.org*)
- The Greater Vancouver Regional District Biodiversity Strategy is a collaborative effort to engage the public, land use planners, and decision-makers in conserving the ecosystem components, functions, and services that remain in the district, which is expected to reach nearly three million people by 2021. (*www.gvrd.bc.ca/growth/biodiversity.htm*)
- Garry Oak Ecosystem Recovery Team (GOERT) partners government, First Nations, non-governmental organizations, academic institutions, and private enterprises in the development and implementation of a recovery strategy for the endangered Garry oak ecosystem. Garry oak and associated ecosystems are home to 104 vertebrate species and more plant species than any other terrestrial ecosystem in coastal British Columbia. (*www.goert.ca/*)
- Nature Canada and Bird Studies Canada work as Canadian partners with BirdLife International to designate Important Bird Areas (IBA) to protect and monitor a network of vital habitats for the conservation of bird populations and biodiversity around the world. Seventy sites have so far met the criteria for Important Bird Areas in BC: 36 islands with seabird colonies, 23 wetland and inland sites, 7 marine sites, 2 heron rookeries, and 2 shorebird migration sites. One tiny island has 55% of the world's population of Cassin's auklets—nearly two million birds. (*www.naturalists.bc.ca/projects/iba/iba_intro.htm*)
- Habitat Stewardship Program (HSP) for Species at Risk is a funding program established in 2000 as part of the National Strategy for the Protection of Species at Risk. The goal is to contribute to the recovery of species by engaging the public in conservation actions that benefit wildlife. The HSP provides funding stewardship projects that protect or conserve habitats for species designated by COSEWIC as endangered, threatened, or of special concern. The HSP is one of the three main federal funding programs centred on protection and recovery of species at risk that are being implemented by Environment Canada, Fisheries and Oceans Canada, and the Parks Canada Agency. (*www.cws-scf.ec.gc.ca/hsp-pih/default.asp*)

- M3, Marine Mammal Monitoring, is one of many ongoing HSP projects (see above) that promotes stewardship of marine mammals, birds, and critical habitat by providing a comprehensive outreach, education, and monitoring program for recreational and commercial ecotourists. To reduce potential impacts of vessel traffic, which can disrupt the natural activities of marine animals, M3 is also developing best management practices guidelines for viewing marine mammals and birds. (*salishsea.ca/m3/M3home.html*)
- BC Trust for Public Lands was established in 2004 to secure and manage ecologically sensitive lands and to plan for biodiversity conservation across the province. The Trust is delivered through the BC Conservation Lands Forum, a partnership between government and the conservation sector. An independent committee under the Forum is developing a provincial biodiversity strategy to inform policy and decision-making. Provincial government news release at *www2.news.gov.bc.ca/nrm_news_releases/2004SRM0036-000815.htm*.

WHAT CAN YOU DO?

British Columbians make many personal choices that affect the natural environment. For example, choosing to consume less resources and produce less waste relieves some of the pressure on the ecosystems that contain BC's biodiversity. The effect of this can be multiplied many times if everyone makes choices that reduce the pressure on the planet's ecosystems. Here are some other things you can do:

- Learn more about the animals and plants in British Columbia. Local natural history societies, as well as national and provincial parks, offer opportunities for learning about flora and fauna in their natural environment. The Federation of BC Naturalists acts as the hub for a network of natural history societies in towns and cities across British Columbia. Find a local club at *www.naturalhistory.bc.ca/VNHS/index.htm*.
- Encourage backyard biodiversity by providing habitat for native animals and plants. Naturescape British Columbia is a program that helps people bring human communities closer to living in harmony with nature, by providing information on how to restore, preserve, and enhance wildlife habitat in urban and rural landscapes and yards. (*www.hctf.ca/nature.htm*)
- Share your knowledge of, and passion for, biodiversity with friends, children, and co-workers. Project WILD provides wildlife-focused conservation education for K–12 teachers and their students. (*www.projectwild.org/*)

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Fisheries

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Fisheries

BACKGROUND

Coastal First Nations people have fished in British Columbian waters for many thousands of years and attach great cultural significance to the marine environment and its resources. Europeans have fished in BC since the 1800s, catching herring, salmon, halibut, and many other species of groundfish, pelagic fish, and invertebrates. The bounty of these fisheries depends on intact coast and marine ecosystems that support spawning, foraging, migration, growth, and reproduction of fish. It also depends on how well humans manage their direct impact on fish through harvesting. Healthy fish stocks and functioning marine ecosystems are important for many marine mammals, seabirds, eagles, bears, and a host of other species that depend at least partly on the marine fish and invertebrates for food.

Economically, the state of fisheries and marine ecosystems is an important issue for the many BC coastal communities that depend on fishing and fish processing. In 2004, commercial landings of all species in British Columbia totalled 265,000 tonnes and were valued at close to $390 million, while the wholesale value to the BC economy was almost $810 million (BCMOE/MAL 2005). Fishing is also a major form of recreation. In the last nationwide survey of recreational fishing in Canada, annual expenditure on recreational fishing in BC tidal waters (direct expenditure plus investments attributed wholly to fishing) was estimated to be almost $500 million (DFO Statistical Services Unit 2000).

Fisheries in British Columbia

The main species caught in BC's coastal waters are Pacific salmon and steelhead trout (in freshwater); groundfish (fish that live on or near the bottom of the ocean); pelagic fish (schooling fish that live at or near the surface); and many species of invertebrates (animals without backbones, such as crabs, shrimp, clams, sea urchins, and squid). Depending on the species, there are commercial trawl fisheries, hook-and-line fisheries, longliners, dive and dig fisheries, troll, gillnet, seine, and trap fisheries. The largest commercial fishery in terms of landings is the groundfish trawl fishery, primarily for hake, halibut, rockfish, and sablefish. There are also recreational fisheries for many species. First Nations people harvest fish and invertebrates for food and ceremonial purposes, as well as actively participate in commercial fisheries.

The federal government has jurisdiction over the sea coast and inland fisheries, fishing in tidal or navigable non-tidal waters, and the power to protect the waters in which fish spawn or live. The provincial government regulates freshwater fisheries in the province and also has authority over fish once they are caught.

Managing Impacts of Fishing

Fish and other species differ widely in their ability to withstand harvest. Short-lived species with a high turnover rate (e.g., shrimp, squid, small pelagic fish) are generally able to sustain much higher rates of harvest than slow-growing species with low rates of reproduction (e.g., rockfishes). It is generally assumed that, for any population of fish, there is an optimum harvest rate. This is based on the assumption that the rate of growth for a population depends on population size and that, within certain limits, harvesting a proportion of a population is beneficial to the remaining individuals because it reduces the competition for resources.

Because fish are hard to observe directly, there is usually a great deal of uncertainty about the status of fish stocks and how they respond to harvesting. There is also uncertainty about the effect of environmental factors, such as climate, on fish stocks and how these factors interact with fisheries. Despite this uncertainty, fisheries scientists try to determine safe levels of harvest and convey this information to fisheries managers who are ultimately responsible for setting the allowable catch. Fisheries scientists study the population dynamics of fish stocks and the fishery's response to management so they can provide information that must be taken into account during management.

Measures used in managing BC groundfish, pelagic, and invertebrate fisheries range from simple to highly sophisticated stock assessment techniques. These measures include indices of recruitment, abundance, harvest rate, catch, and catch per effort. Even the best stock assessment techniques, however, cannot completely remove uncertainty in managing stocks. Many fisheries agencies around the world, including Canada, buffer against uncertainty by using precautionary management tactics such as limiting fishing effort (by restricting licences, days, or areas fished) or using cautious quotas.

Fishing has a negative impact when stocks are overfished, and can have other, indirect, impacts on ecosystems. Overfishing occurs when a fish stock (i.e., a discrete population of fish) is harvested at a higher rate than the rate at which it can grow. Immigration aside, the biomass of a fish population grows by recruitment (adding new juveniles) and by growth in size of individuals. Overfishing can affect one or both of these processes, by harvesting too many fish before they have had a chance to spawn or by harvesting fish before they have the opportunity to grow larger. Although some reduction in size or age of fish is normal when stocks are exploited, a large reduction in either or both factors is a concern.

Scientists are becoming increasingly aware that commercial fishing may have a wider impact on marine ecosystems than just on the species that are directly targeted. Fisheries can alter the structure of marine ecosystems and increase their instability and unpredictability by:

- selectively removing large, long-lived species that are less able to withstand high fishing mortalities than smaller, short-lived species;
- altering habitats by fishing gear such as bottom trawl nets;

- reducing predator pressure coming from large fish, which leads to greater abundance of small fish and squids (e.g., "fishing down marine foodwebs"; Pauly et al. 1998);
- causing trophic cascades, which occur when a reduction in the number of top predators allows populations of lower trophic-level fish to increase; in turn, they deplete their food supply of organisms still lower on the food chain (e.g., Pinnegar et al. 2000).

Monitoring to detect signs of overfishing (such as reduced abundance or smaller fish in the catch) is one of the main roles of fisheries management agencies. Although that is not an easy task, monitoring to detect impacts of fishing on ecosystems is an even more difficult problem. Establishing clear explanations for changes in the relative abundances of interacting species is complicated, partly due to the great complexity of food webs (May et al. 1979; Yodzis 1994).

Fisheries Indicators

Most indicators in this paper use data that were collected to manage commercial fisheries. Although this is not a review of the commercial fishing industry, fishery-based indicators are used partly as a proxy for the status of marine ecosystems and partly as a measure of direct human pressures, mainly from fishing, on those ecosystems. Indicators show overall status and in some cases trends, but do not show which of the many contributory factors have the most weight; such factors are complex, numerous, and vary with location and species. This is the reason for using a suite of indicators to detect changes in marine ecosystems—rather than relying on one indicator—to provide a broader picture of what is happening in the ocean (e.g., Rice 2000; Link et al. 2002; Hall and Mainprize 2004).

As with all state-of-environment reporting, undesirable results of indicators signal that more must be done to discover causes and take effective action to address influences that are under human control. A key response indicator in this paper addresses the latter point by attempting to quantify the effect of efforts to reduce the negative impacts of commercial fishing on non-target species.

Indicators were chosen to provide a broad, coast-wide assessment wherever possible. They are based on data available at the time of writing from websites and published research.

INDICATORS

1. Key Indicator: Proportion of salmonid populations that are classed as healthy, at moderate to high risk of extinction, or extinct

This is a status indicator. It address the question: What is the current status of British Columbia's salmon? Such an overall assessment of the status of salmon populations shows the net effect of:

- the overall state of terrestrial and oceanic ecosystems on which salmon depend, including impacts from human activity ranging from direct impacts on spawning streams to the global impacts of climate change;
- the direct impact of fishing and fisheries management practices; and
- naturally occurring factors and changes that are outside of human control.

This indicator infers the risk of extinction based on the trends in spawning salmon populations. It is intended to provide an overview by estimating the risk of extinction of a large number of salmon populations over the entire length of the northwest coast. The unit used in this indicator is a "spawning population" (a unique combination of species and stream). Note that this is not the same unit as a "stock" as defined for fisheries management purposes, which includes genetic relationships in defining a stock, a stock group, or conservation unit.

Salmon are anadromous, meaning that they spawn (breed and lay eggs) in freshwater but spend most of their adult life in the marine environment. Native anadromous salmon species found in British Columbia include chum (*Oncorhynchus keta*: ~1450 populations), coho (*O. kisutch*: ~2400 populations), sockeye (*O. nerka*: ~900 populations), pink (*O. gorbuscha*: ~2100 populations), chinook (*O. tshawytscha*: ~780 populations), and steelhead trout (*O. mykiss*: ~850 populations) (Riddell and Tautz 2003). It is estimated that there are more than 22,300 spawning populations of salmonids in North America (Waples et al. 2001), of which approximately 9080 are located in the BC/Yukon region (Slaney et al. 1996, excluding the Strait of Georgia).

Pacific salmon spawn in gravel beds in rivers, streams, or along lake shores. Depending on the species, juveniles may spend a few months to 3 years in freshwater or estuaries before migrating to the ocean. Salmon spend between 18 months and 5 years in the ocean, depending on the species, and may migrate extensively. A great deal remains unknown about these migration patterns (e.g., Eggers et al. 2003). At the end of the ocean stage, salmon return from the sea to spawn in the same streams from which they hatched. Most species die after spawning, although steelhead may spawn in successive years. Table 1 summarizes the life histories and diet of the seven species.

Table 1. Life cycle and food requirements of chum, chinook, sockeye, coho, and pink salmon and steelhead trout.

Species	Freshwater stage	Primary diet in ocean	Ocean stage	Total lifespan
Chum (keta)	Up to 6 months; fry migrate Feb.-June, immediately upon hatching, with most migrating April-May.	Mainly copepods; also crustaceans, squid, fish.	2-5 years; migrating adults present in coastal waters July-Oct.	2-7 years, with most living 3-5 years; adults die after spawning.
Coho (silver)	Juveniles overwinter in coastal streams and small lakes; remaining in freshwater 1-3 years.	Insects, copepods, other invertebrates and small fish.	1-2 years males; 2 years females.	3 years; adults die after spawning.
Sockeye	Juveniles overwinter in coastal watersheds and remain in lakes 1-3 years, migrating from streams in the spring; a few go directly to sea.	Plankton, krill, and small crustaceans.	1-4 years, returning to spawn in late summer and fall.	3-5 years; adults die after spawning.
Pink	Fry migrate from rivers and streams mid-April to mid-May; they spend the least time in fresh water of all species.	Mainly copepods, other plankton and crustaceans; also small fish.	18 months.	2 years; adults die after spawning.
Chinook (king or spring)	"Ocean-type" migrate late summer, 1-3 months after emergence; some overwinter and migrate the next year. "Stream-type" migrate during 2nd or 3rd spring.	Copepods and other invertebrates; small fish supply larger part of diet than for other species.	4-5 years; (2 or more for males; 3-4 for females).	3-6 years; adults die after spawning.
Steelhead	1-2 years in coastal streams; most hatch in early summer and migrate from rivers the next spring.	Fry eat bottom-dwelling invertebrates, fish eggs, plankton; also small fish and crustaceans.	1-4 years; "summer run" steelhead enter rivers spring-late summer, spawn the next spring. "Winter run" fish enter rivers late fall or winter, spawn in spring.	Adults can migrate and spawn repeatedly.

Threats to Salmon Populations

The following is a list of known and potential threats to BC salmonids; the type and impact of threats varies with the stock:

- Overexploitation: Smaller or less productive stocks mixed with larger or more productive stocks are vulnerable to overfishing. Failing to account for mixed stock structure in overexploited populations can lead to underestimation of optimum escapement and overestimation of safe harvest rates, and prevent recovery of less productive stocks (Hilborn 1985).
- Alteration of spawning and rearing habitat: Changes to spawning habitat can affect the survival of spawning adults, eggs, or juveniles. Alterations include construction of dams (Levin and Tolimieri 2001) and impacts from mining, gravel removal, water impoundment, and other human activities. Land clearing (i.e., for urban development, agriculture, logging) increases runoff, which increases nutrient levels, erosion, and sedimentation in streams and reduces the natural vegetation that shades streams and regulates the water temperature (e.g., Regetz 2003). (Note: Habitat alteration from human activities is not always detrimental, e.g., Walters 1975; Walters and Martell 2004.)
- Alteration of marine rearing habitat: Impacts from human activities include loss of estuarine area, impacts from log handling and booming, waste discharge and contaminants in effluents, development of marinas and aquaculture. The escape of Atlantic salmon (*Salmo salar*) from net pens used in BC's aquaculture industry has caused concern about the potential for competition with wild stocks (e.g., Neilsen 2003). Another area of controversy, currently under study by Fisheries and Oceans Canada, is the impact of sea lice (a small, parasitic crustacean) on the health of wild pink salmon and whether this is related to net-pen aquaculture in the Broughton Archipelago.
- Ocean conditions: Sea surface temperature, salinity, and ocean currents have been correlated with migration timing and pathways (e.g., Flynn and Hilborn 2004). Predation by marine mammals and competition for food with other species also affect marine survival. Another component of ocean conditions could be considered the exponential increase in released hatchery salmon into the ocean from all countries around the North Pacific. Nielsen (2003) estimates that introductions have exceeded 6 billion fish per year for the last decade (see next point).
- Hatchery programs: Beginning in 1977, the Canadian Salmonid Enhancement Program sought to improve stream conditions and double the catch of Pacific salmon and steelhead through stocking programs. In 1998, 429 million salmon were released from BC hatcheries and up to 80% of the coho caught in BC coastal waters were attributed to enhancement programs (Noakes et al. 2000). Concerns about the effect of hatchery fish on wild salmon populations have led to a re-evaluation of the impacts of hatchery production on natural populations (reviewed in Nielsen 2003). Such concerns include competition with wild salmon for resources, increased fishing pressure on wild stocks as the presence of hatchery fish attracts fishing effort, harvest

of eggs and fry from wild populations, increased predation or disease of wild stocks as predator and parasite populations increase in response to the abundance of hatchery salmon, and genetic change in wild stocks that interbreed with hatchery fish (reviewed in Gardner et al. 2004).

- Climate change: Strong correlations have been found between salmon productivity in BC and the decade-long oscillations in climate and ocean conditions called the Pacific Decadal Oscillation (PDO) (e.g., Mantua et al. 1997; Beamish et al. 1999). The type of changes seen in the warm phase of the PDO may presage the type of changes in store as the global climate changes. Changes in oceanic temperature and circulation patterns cause changes in production of the phytoplankton (single-celled algae) that form the base of the oceanic food chain, ultimately affecting the productivity of salmon in the ocean.

ENDANGERED SALMON

At the time of writing, three populations of salmon were listed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC):

- Interior Fraser coho
- Sakinaw Lake sockeye
- Cultus Lake sockeye

The federal Minister of Environment decided not to add the Sakinaw and Cultus Lake populations to Schedule 1 of the Species at Risk Act (SARA), meaning that they have not been officially listed as Wildlife at Risk in Canada. Once a species is added to the list and protected officially under SARA, a recovery strategy must be developed. A decision on the status of the Interior Fraser coho is pending.

Methodology and Data

Riddell and Tautz (2003) reviewed the extinction risk of 6692 populations of Pacific salmon in North America as described in *Fisheries*, the American Fisheries Society's journal (Nehlsen et al. 1991; Baker et al. 1996; Huntingdon et al. 1996; Slaney et al. 1996). Riddell and Taut defined four categories of extinction risk using trends in spawning numbers or information available, following the definitions as defined by Nehlsen et al. (1991). The four risk categories are:

1. High risk of extinction: Populations whose spawning numbers are declining. Fewer than one adult fish returns to spawn for each parent spawner. This category includes populations with recent escapements under 200 spawners, in the absence of evidence that they were historically small. ("Escapement" refers to the number of mature salmon that escape capture by fisheries and other forms of mortality to return to their rivers of origin to spawn.)

2. Moderate risk of extinction: Populations whose spawning escapements appear stable after previously declining more than natural variation would account for, but that exceed 200 spawners.

3. Special concern: Populations for which:
    - Relatively minor disturbances could be a threat;
    - Insufficient information on population trend exists, but available information suggests they are depleted;
    - Relatively large ongoing release of non-native fish and the potential for interbreeding with the native population exists; or
    - The population is not presently at risk, but requires attention because of a unique character.
4. Extinct: Populations that were known to exist previously, but the native fish are known to no longer spawn in the original habitats.

Populations at risk are summarized by geographic region in Table 2 and Figure 1 and by species in Table 3 and Figure 2. Note that "Special Concern" and "Moderate Risk" categories were combined because numbers in these categories were low (Riddell and Tautz 2003).

Table 2. Proportion of assessed populations of Pacific salmon (chinook, coho, sockeye, chum, pink, steelhead) by risk category and geographic region.

Geographic region	No. of assessed populations	No to low risk of extinction (%)	Special concern to moderate risk (%)	High risk of extinction (%)	Extinct (%)
Pacific Northwest states[a*]	404	24.5	25	20.3	30.2
BC and Yukon[b]	5358	81.4	5.1	11.4	2.1
SE Alaska[c]	930	98.6	1.0	0.2	0.2

Source: Riddell and Tautz (2003).

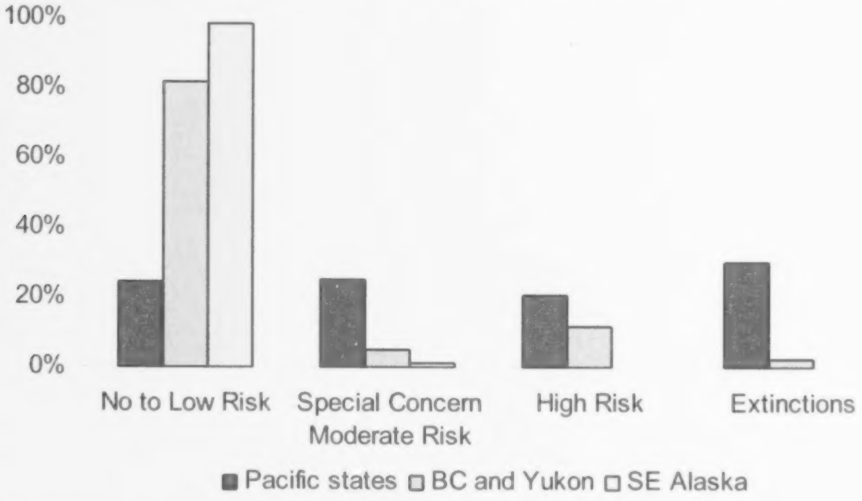
* Includes populations from Canadian parts of Strait of Georgia.

[a] Nehlsen et al. 1991; Huntingdon et al. 1996.

[b] Slaney et al. 1996 (excludes populations from Canadian parts of Strait of Georgia).

[c] Baker et al. 1996.

Figure 1. Proportion of assessed populations of Pacific salmon (chinook, coho, sockeye, chum, pink, steelhead) by risk category and geographic region.



Source: Riddell and Tautz (2003).

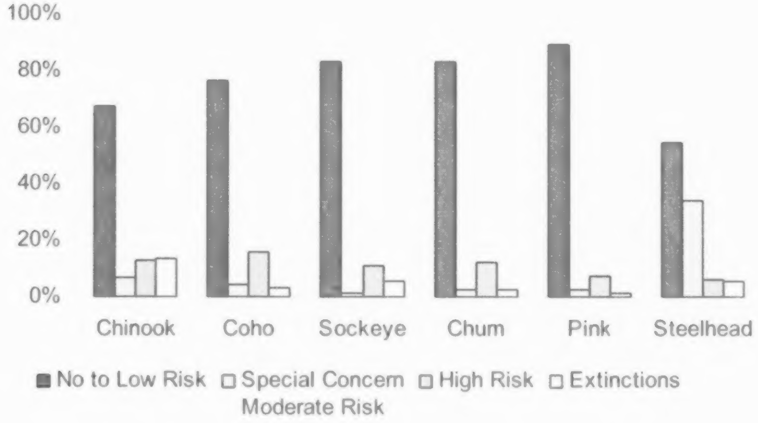
Table 3. Proportion of assessed populations of Pacific salmon by species and risk category.

	Chinook *n* = 587	Coho *n* = 1435	Sockeye *n* = 590	Chum *n* = 1240	Pink *n* = 2254	Steelhead *n* = 586
No to low risk	67.3	76.45	83.05	82.9	89.3	54.3
Spec/Moderate risk	6.8	4.32	1.02	2.6	2.2	34.1
High risk	12.8	16.03	10.68	12	7.4	6
Extinctions	13.1	3.2	5.25	2.5	1.1	5.6

Source: Riddell and Tautz (2003).

n = number of populations assessed.

Figure 2. Proportion of assessed populations of Pacific salmon by species and risk category.



Source: Riddell and Tautz (2003).

Comparison of BC populations with those of neighbouring jurisdictions shows that half (50.5%) of the populations in the Pacific Northwest states (US) are extinct or at high risk of extinction. This compares to 13.5% in British Columbia and the Yukon and only 0.4% in southeast Alaska.

Assessment of salmon populations relative to their risk of extinction based on the spawning escapement is a relatively coarse indicator and one that does not show early declines in populations. Although a quantitative analysis based on changes in total production (catch plus spawners) over time would be a better indicator of salmon status, catch data are not available for all spawning populations and further work is required to determine reference points for categorizing levels of concern.

Interpretation

Riddell and Tautz (2003) viewed these results as encouraging for Canadian Pacific salmon populations and as more optimistic than might have been expected. It should be noted, however, that a larger proportion of Canadian populations were at risk than those of southeastern Alaska, and populations from the Canadian part of the Strait of Georgia were excluded from the BC/Yukon part of the analysis and were included with the Pacific Northwest states. The Strait of Georgia is the most developed and heavily populated region in BC and the site of the Fraser River fisheries, BC's largest Pacific salmon fisheries.

The status of a particular salmon population reflects the net impact of fishery management practices as well as other factors (human caused and naturally occurring) that alter conditions in their freshwater and marine habitats. Factors affecting survival in the oceanic phase of salmon life cycles are not as well understood as those that affect their freshwater environments. Substantial resources have been allocated to researching and restoring freshwater salmon habitats, but relatively few resources have been directed toward understanding factors affecting marine survival of salmon.

One of the main issues affecting salmon populations and salmon biodiversity is that many small stocks are fished in mixed stock complexes. Walters (2003) maintains that the basic issue facing salmon managers is that there is no way to manage these complexes without putting at least some of the smaller populations at risk of extinction. Management of such stocks (e.g., by setting low harvest rates for the mixed stock fishery) involves consideration of the difficult trade-off between social and economic values of the harvest and the benefits of maintaining salmon biodiversity.

2. Secondary Indicator: Current outlook of managed salmon stocks in BC

This is a status indicator. It addresses the question: What is the status of commercially fished salmon stocks in BC?

Indicator 1 provided an overview of the risk of extinction of many of the salmon populations along the entire coast. This supplementary indicator provides the current outlook for the managed salmon stocks, by species, relative to an assessment of the target abundance of fish for each stock. Note that the unit used in this indicator, the "stock" as defined for fisheries management purposes, is a different unit than the salmon populations used in Indicator 1. Like the previous indicator, however, the outlook for each stock portrays the net effect of environmental factors as well as the effects of fishing and fisheries management.

Methodology and Data

The 2004 stock outlooks for managed BC salmon stocks were obtained from Fisheries and Oceans Canada (DFO 2003e). The Stock Assessment group of DFO assigns each stock group a status outlook that reflects the available quantitative and qualitative information on recent returns for each stock, as well as the expert opinion of fisheries managers on its status. The outlook is relative to the target abundance for that stock for fisheries planning; where stock targets have not been formally described, targets were either historical levels of abundance or were based on expert opinion (DFO 2003e).

Stock status outlook is rated according to where stock is (or is forecast to be) on a scale of 1 to 4:

1 = Stocks are less than 25% of target abundance or declining rapidly.

2 = Stocks are well below target or below target and declining.

3 = Stocks are within 25% of target and stable or increasing.

4 = Stocks are well above target abundance.

Some (23) stocks were assigned a range of outlook categories, reflecting the significant geographic variation in status within the stock group. Stocks given ratings of 1 or 1/2 were counted together, stocks rated as 2, 2/3, or 2/4 were counted together, and stocks rated as 3 or 3/4 were counted together.

The 2004 outlooks for a total of 87 managed stock groups (populations) of sockeye, chinook, chum, coho, and pink salmon are shown in Table 4.

Table 4. Number of BC managed salmon stocks rated in each status outlook category (1 to 4) and proportion of the total number of stocks in each category.

Species	No. stocks assessed	Stock outlook category			
		1, 1/2	2, 2/3, 2/4	3, 3/4	4
Sockeye	29	6	10	11	2
Chinook	23	1	7	9	6
Coho	18	0	8	8	2
Pink	6	0	4	1	1
Chum	11	4	4	2	1
Total	87	11	33	31	12
Proportion of total		12.6%	37.9%	35.6%	13.8%

Source: DFO (2003e).

Note: No data were available for one stock of coho and three stocks of pink salmon.

According to the stock outlooks for the 2004 year analysed for this indicator, 43 of the stock groups assessed, or about half (49%), were forecast to be in categories 3 and 4, meaning they are stable, increasing, or well above target—in other words, not of concern. Thirty-three stock groups (about 38%) were in category 2 or had part of the stock group rated in this category. This group consists of sensitive stocks that are well below target abundance or well below target and declining. Eleven stocks (about 13%) were rated in category 1—stocks that are expected to be of the greatest concern because they are at less than 25% of target abundance or are declining rapidly.

Interpretation

It is important to note that year-to-year variations in stock status occur as different year classes of salmon return. This analysis shows that about half of the stock groups were forecast for 2004 to be in categories 1 or 2 and half of the stocks were rated in category 3 or 4. Chum had the highest percentage of stocks in the two lower categories (8 of 11 stocks). Three of these stocks (the Taku and two Yukon stocks) are transboundary stocks that are caught in Alaskan and Canadian fisheries. Precautionary fishing practices in both countries appear to be resulting in improved escapement for these stocks (DFO 2003e). For the other species, poor marine survival (as juveniles or adults), leading to low numbers of returning spawners, has contributed to the depressed levels of many of the stocks listed in categories 1 or 2 (DFO 2003e).

Stocks that are forecast to be in categories 1 and 2 are considered to be "sensitive," meaning that, where possible, fisheries would be planned to reduce impacts on these groups (DFO 2003e). Possible consequences for fisheries implied by the four outlook categories, are listed in Table 5.

Table 5. Fishery consequences implied by the stock outlook categories.

Stock outlook	Fishery consequence
1	Directed fisheries are unlikely and there may be a requirement to avoid indirect catch of the stock.
2	Directed fisheries are uncertain and likely to be small if permitted. Allocation policy will determine harvest opportunities.
3	Directed fisheries subject to allocation policy.
4	Directed fisheries subject to allocation policy.

Source: DFO (2003e).

Conservation requirements for stocks in categories 1 and 2 may limit fishing opportunities for stock groups for which there are no concerns. For example, restrictions on fisheries in several regions have been implemented to protect the endangered Cultus salmon stock (DFO 2004a).

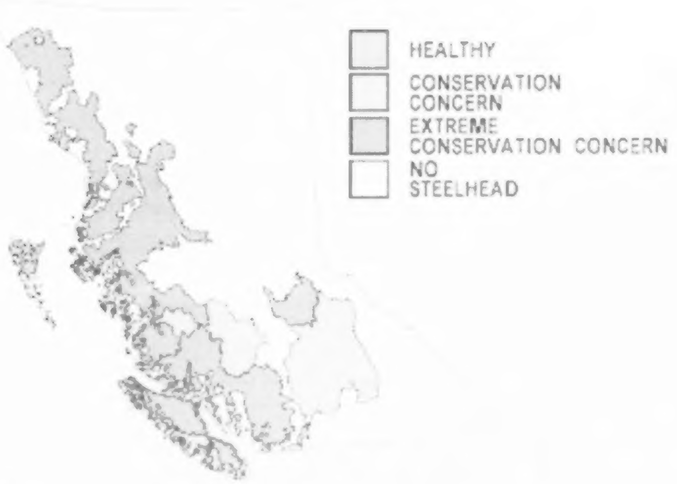
Supplementary Information: Conservation Status of Steelhead in the Lower Mainland

Steelhead (*Oncorhynchus mykiss*) are highly valued by recreational anglers and are important in First Nations ceremonial, social, and food fisheries. The Steelhead Recovery Plan (Lill 2002) classifies wild steelhead stocks relative to the capacity of a watershed to produce and sustain steelhead into the following categories:

- Special Concern (SC): Mostly small stocks in probable need of conservation but for which little or no stock assessment information is available.
- Routine Management Zone (RMZ): Stocks above 30% of habitat capacity in most years and not threatened in terms of genetic and environmental distinctiveness; can withstand modest catch and release fisheries.
- Conservation Concern (CC): Stocks estimated to be at 10–30% of habitat capacity. Limited catch-and-release angling may be possible for stocks in the upper part of this range.
- Extreme Conservation Concern (ECC): Stocks believed to be at 10% or less of habitat capacity and likely to become extinct if they are in decline for more than one or two generations.

The status of steelhead trout stocks over the whole province was reported in *Environmental Trends in British Columbia: 2002* (BCMWLAP 2002). About half of the stocks in BC that were assessed at that time were classed as healthy and about half were classified as either of Conservation Concern or of Extreme Conservation Concern. Most of the latter occurred in the Lower Mainland and Vancouver Island (Figure 3), where 93 to 95% of stocks were rated as being of Conservation Concern or Extreme Conservation Concern (Lill 2002). Most conservation efforts are being allocated in this region.

Figure 3. Assessed conservation risk to steelhead stocks in 2002.



Source: BCWLAP 2002.

In 2002, most of the steelhead stocks classified as of Conservation Concern or Extreme Conservation Concern occurred in the Greater Georgia Basin (BCMWLAP 2002). At that time, the wild steelhead stocks in 48 of the 58 highest priority watersheds were classified as in decline or at very low levels, with 51 of 55 (93%) winter-run and 21 of 22 (95%) summer-run stocks of Conservation Concern or Extreme Conservation Concern (Lill 2002).

Further research on the 2005 status of steelhead in the Fraser River watershed are shown in Table 6 (R. Ahrens, UBC Fisheries Centre, 2005, pers. comm.). These assessments are part of the Steelhead Recovery Plan, which is completing stock assessments for all priority watersheds (*www.bccf.com/steelhead/about-steelhead.htm*). The objectives of the recovery plan are to stabilize and restore wild steelhead stocks and habitats to healthy self-sustaining levels and to maintain or restore angling opportunities (Lill 2002).

In 2005, 30 watersheds were assessed using methods similar to those used in 2002 (Table 6), but the 2005 analysis did not use the category Special Concern (SC). Stocks for which there were too few data to complete the assessment but that showed a likely decreasing trend were placed in the Extreme Conservation Concern (ECC) category. Thus five stocks rated as SC in 2002 were assigned to ECC in 2005; however, they are not counted as stocks that declined because the change does not indicate a real change in status (see Table 6).

In 2005, 10 of the 30 watersheds studied in 2002 were reassessed and 20 watersheds were assessed for the first time. In 2005, all watersheds were rated as of Conservation Concern or Extreme Conservation Concern. The status of 4 of the 10 watersheds assessed in 2002 had declined; 2 moved from CC to ECC; and 2 rated healthy (Routine Management Zone) in 2002 declined to Extreme Conservation Concern.

Declines in steelhead abundance are believed to have been caused by greatly reduced ocean survival combined with low productivity in freshwater habitats. Depending on the location of the stock, factors that may affect freshwater productivity include impacts from logging, urban development, agriculture, hydroelectric projects, and other changes to water flow (Lill 2002).

Table 6. Condition of steelhead for 30 Fraser River watersheds in British Columbia.

Unit	Watershed	2005 status*	2002 status
Mid Fraser summer	Chilcotin River	CC	–
	Taseko River	CC	–
Boundary Bay	Campbell River	ECC	–
	Nicomekl River	ECC	–
	Serpentine River	ECC	–
Lower Fraser	Vedder-Chilliwack	CC	–
	Coquitlam River	ECC*	CC
	Pitt River	ECC*	CC (Upper Pitt)
	Alouette River	ECC*	RMZ
	Widgeon Creek	ECC	–
	Kanaka Creek	ECC	ECC
	Salmon River	ECC	SC
	Norrish Creek	ECC	SC
	Weaver Creek	ECC	–
	Cogburn Creek	ECC	–
	Big Silver Creek	ECC	SC
	Lillooet River	ECC	–
	Birkenhead River	ECC	–
Lower Fraser summer	Silverhope Creek	ECC	SC
	Coquihalla River	ECC	SC
	Chehalis River	ECC*	RMZ
Fraser Canyon	Nahatlatch River	ECC	–
	Stein River	ECC	–
	Seton River	ECC	–
	Bridge River	ECC	–
Mid Fraser summer	Thompson River	ECC	–
	Nicola River	ECC	–
	Bonaparte River	ECC	–
	Deadman River	ECC	–
	Quesnel River	ECC	–

Source: 2005 data from R. Ahrens, Fisheries Centre UBC; 2002 data from Lill (2002).

SC = Special Concern, RMZ = Routine Management Zone, CC = Conservation Concern, ECC = Extreme Conservation Concern, – = not assessed.

* Indicates a decline in status from 2002.

Supplementary Information: Outlooks for stocks of groundfish, pelagic fish, and marine invertebrates in BC

This section addresses the question: What is the status of the important commercial fish species in BC? Such a general question, however, cannot be answered either simply or, at this time, in any quantitative way.

The information in this section is not an indicator because it does not report quantitative data and cannot be used as a baseline measure or to show a trend. It was included to provide descriptive summaries of the status of commercially fished species and is based on assessments available at the time of writing. Given the diverse life histories of the many species and the limited knowledge of stock structure for most of these species, a single status indicator likely would not be possible or appropriate.

Fisheries and Oceans Canada publishes stock status reports for 23 species of groundfish, 5 pelagic fish species, and 16 marine invertebrates. In addition, Pacific halibut is assessed and managed by the International Pacific Halibut Commission. For species that are assessed, assessment methods vary considerably, depending on the type and quantity of data available. In some cases, only certain populations of each species are assessed. Methods used to assess the status of stocks range from simple analysis of trends in commercial landings and catch effort data to the use of complex analytical models based on various types of data collected in fisheries-independent surveys.

The following brief summaries of species or groups are based on stock status reports (*www.pac.dfo-mpo.gc.ca/sci/psarc/SSRs/ssrse.htm*) and integrated fisheries management plans (*www-ops2.pac.dfo-mpo.gc.ca/xnet/content/MPLANS/MPlans.htm*) published by Fisheries and Oceans Canada, as well as other sources as cited (DFO 1998, 1999a-v, 2000a,b, 2001a-c, 2002a-k, 2003a-d, 2004a-j, 2005a,b). Although stock outlooks used in the descriptions were the most recent available at the time of writing, in some cases the most recent reports available were from 1999. Periodically more recent reports are posted on the above websites.

Groundfish

Groundfish is a broad term used to describe fish that live on or near the bottom of the ocean as well as in the mid-levels of water. Four groundfish fisheries occur in the Pacific region: groundfish trawl; halibut by hook and line; sablefish by trap and hook and line; and rockfish and other species by hook and line. The largest of these is the trawl fishery, which lands 77 species (of which 27 are assessed). Landed value of groundfish in 2004 was $90 million, with a wholesale value of $261.4 million (BCMOE/MAL 2005).

Pacific halibut (*Hippoglossus stenolepis*)

Halibut are a highly important commercial, First Nations, and recreational species and are the most valuable species of groundfish harvested in BC, with a wholesale value of $90 million in 2004 (BCMOE/MAL 2005). The commercial fishery operates along the US and Canadian Pacific coast. The fishery is assessed yearly by the International Pacific Halibut Commission, using commercial fishery data and data from surveys and tagging programs (e.g., Clark and Hare 2003). Halibut stocks in Canada and Alaska were at an historical low in the 1970s, but increased over the next 20 years. Female spawning biomass is currently estimated to be 2 or 3 times the 1970s level. Recent average recruitment has been good by long-term historical standards and stocks are considered stable and healthy (DFO 2004b).

Pacific Ocean perch (*Sebastes alutus*)

In terms of landed catch, Pacific Ocean perch is the most important rockfish species in the BC trawl fishery. The fish ranges from southern California to the Bering Sea and is generally captured by trawl gear over cobble and rocky areas. The main part of the Canadian fishery occurs in Queen Charlotte Sound (Goose Island, Mitchell's, and Moresby gullies). Records of catches began in 1954, but until the 1970s, similar rockfish species were also reported as "ocean perch" or "red rockfish." Reliable biomass estimates for Pacific Ocean perch are available for the Goose Island Gully population. According to the most recent stock assessment available for Goose Island Gully, 1984 to 1995, the stock was estimated to have increased due to high recruitment and low fishing mortality; numbers have climbed to about half what they were in 1965 (DFO 1999a). In 1999, the stock was estimated to be declining slightly due to poor recruitment.

Lingcod (*Ophiodon elongatus*)

Lingcod occur from California to Alaska and inhabit nearshore rocky areas (King et al. 2003). The stock consists of an inshore stock in the Strait of Georgia and offshore stocks off the west coasts of Vancouver Island and Haida Gwaii, Queen Charlotte Sound, and in Hecate Strait.

The inshore fishery was closed to commercial fishing in 2002 (DFO 2002a). Conservation concerns for inshore rockfish and lingcod led to the development of the Rockfish/Lingcod Conservation Strategy, announced in 2002 (DFO 2002b). To date, 89 key habitat areas have been closed to fishing to protect inshore rockfish and lingcod.

Offshore lingcod are exploited primarily by the groundfish trawl fishery, with most of the catch taken from the southwest coast of Vancouver Island. Large catches are also taken from Queen Charlotte Sound. Offshore lingcod stocks are thought to be at a moderate level of abundance, although the status of the stock off the west coast of Haida Gwaii is unknown and a conservative approach to managing the offshore fishery is being taken (DFO 2002a)

Sablefish (*Anoplopoma fimbria*)

Sablefish (black cod) inhabit the continental shelf and slope along the entire west coast. The sablefish fishery is one of the most important in BC, valued at $29 million in 2000. Most of the product is exported to Japan. Sablefish are mostly caught in traps, although some are also caught with longlines or trawl gear. The biomass of sablefish that could be trapped decreased from the 1990s until recently. The current assessment shows that abundance increased through 2004 (DFO 2005b).

Pacific cod (*Gadus macrocephalus*)

Four stocks of Pacific cod are defined for management purposes in BC: Strait of Georgia, west coast of Vancouver Island, Queen Charlotte Sound, and Hecate Strait. Little information is available about any of these stocks except for the Hecate Strait stock, which is fished mainly with trawls. In 1999, the stock was estimated to be at a historical low, and stock projections suggested that the spawning stock biomass would continue to decrease through 2001 (DFO 1999c).

Pacific hake (*Merluccius productus*)

Hake are the second largest harvest in BC by volume, with 2004 landings of 124,900 tonnes. There is a BC offshore stock of Pacific hake and a smaller inshore stock in the Strait of Georgia and Puget Sound. The offshore stock migrates seasonally from southern California to northern British Columbia and is caught using large, mid-water trawls. The fishery is now managed and allocated under a Canada-US agreement. Stock size was relatively stable from 1972-1982, peaked in 1987, and then declined steadily to a historical low in 2001 (DFO 2003b). The United States declared the offshore stock overfished in 2002 when the spawning stock was 25% of the pristine level of abundance. The 2004 assessment found that higher than expected recruitment in 1999 had increased the abundance of females spawning over the next three years, bringing the stock estimates closer to 50% of pristine abundance (Canada-US Pacific Hake STAR Panel 2004).

Rockfish and thornyheads (*Sebastes* spp. and *Sebastolobus* spp.)

Approximately 28 species of rockfish are caught commercially in BC. They are very long-lived fish with low productivity, making them vulnerable to overfishing. Inshore species are caught mainly in the groundfish hook and line fishery. Offshore species are caught in a hook and line fishery and a trawl fishery.

The status of many offshore rockfish stocks is poorly understood. Abundance is thought to be low or declining and many stocks may be fully exploited. Bocaccio is currently listed as threatened by COSEWIC, which is in the process of preparing species status reports for five species of rockfish.

Serious conservation concerns for inshore rockfish species led to the development of the Rockfish/Lingcod Conservation Strategy in 2002 (DFO 2002b). Under the strategy, 89 areas have so far been closed to fishing to protect inshore rockfish, with the eventual aim of closing up to 30% of the rockfish habitat in the Strait of Georgia. Just under 20% of rockfish habitat on the West Coast of Vancouver Island, Central Coast, North Coast, and Haida Gwaii has been set aside in Rockfish Conservation Areas.

Sole (Family Pleuronectidae)

Five main species of flatfish are caught in the groundfish trawl fishery:

- Two species of rock sole (*Lepidopsetta bilineata* and *L. petraborealis*) are caught in a directed fishery in Queen Charlotte Sound and Hecate Strait and also as incidental catch in the Pacific cod fishery. In recent years quotas have been reduced for this species because of low recruitment, possibly due to changes in climatic conditions (DFO 1999m).
- Dover sole (*Microstomus pacificus*) is caught off the West Coast of Vancouver Island and Haida Gwaii. Both stocks appear to fished close to their maximum sustainable yield, and quotas have been introduced to reverse declines in abundance (DFO 1999n).
- English sole (*Parophrys vetulus*), the largest stock (Hecate Strait), is caught in a directed trawl fishery and as bycatch in rock sole and Pacific cod fisheries. Biomass in this fishery is estimated to be above the 50-year average and abundance has stabilized with no change expected (DFO 1999o).
- Petrale sole (*Eopsetta jordani*) occurs in two main populations (off the south coast of Vancouver Island, and Queen Charlotte Sound and Hecate Strait), and appears to be rebuilding after the directed fishery was closed in the mid-1980s and a bycatch cap put in place (DFO 1999p).

Populations of English sole, rock sole, and other species in the Hecate Strait have shown apparent cyclic trends in abundance over the past 50 years that may be related to oceanic conditions (DFO 1999o).

Pelagic Fish

Pelagic fish inhabit the water column and surface waters and often occur in large schools. Small pelagic fish (such as sardines, anchovy, and herring) tend to be caught in seine nets. The largest pelagic fishery in BC at present is the herring roe fishery, with a wholesale value of $83.5 million in 2004. The second largest is the albacore tuna, which are caught by troll gear; in 2004, the wholesale value was $36.3 million (BCMOF/MAL 2005). Minor fisheries have at times existed for Northern anchovy and surf smelt.

Pacific herring (*Clupea pallisii*)

Pacific herring are among the most abundant fish species on the coast of BC. Herring in BC are divided into five major migratory stocks and a number of minor stocks that spawn outside the five main stock assessment areas (Schweigert 2004). Herring have been harvested in BC since the late 1800s.There was a herring reduction fishery (which produced fishmeal and fish oil) which collapsed in 1967; since 1972 there has been a herring roe fishery (Schweigert 2004). A herring spawn-on-kelp fishery is managed separately and occurs in all areas except the Strait of Georgia. The fishery operates by suspending lines of kelp in enclosed ponds or along the shoreline where herring are expected to spawn. There is also a small food and bait fishery targeting winter migratory stocks.

Three of the five main stocks appear to be stable, with sufficient levels of abundance (Prince Rupert, Central Coast, and Strait of Georgia), but two stocks are declining due to poor recruitment (Haida Gwaii and West Coast Vancouver Island) (Schweigert, in press).

Albacore tuna (*Thunnus alalunga*)

The troll fishery for albacore tuna is one of the top ten fisheries in landed value in BC. It is assessed by international bodies: the Inter-American Tropical Tuna Commissions (IATTC) and the Western and Central Pacific Fisheries Commission. The most recent assessment shows that the North Pacific albacore is currently fully exploited and speculates that it may currently be fished at levels above what is sustainable in the long term. IATTC is recommending measures to avoid increasing the impact of fishing on stocks (IATTC 2005).

Eulachon (*Thaleichthys pacificus*)

Eulachon are a culturally important species to coastal First Nations. The fish are rendered down to extract the oil and are also eaten. Except for the Fraser River, there are currently coast-wide recreational and First Nations fisheries for eulachon. The Fraser has been closed to commercial eulachon fishing since 1999 due to extremely low returns of spawners (DFO 1999b). In 2004, the Fraser River stock was estimated to be at a 10-year historical low (DFO 2004c) and there are anecdotal reports of reduced eulachon runs in some central coast rivers. Threats to long-term sustainability include capture of eulachon as bycatch in trawl fisheries, river pollution, and predation by marine mammals (DFO 1999b).

Pacific sardine (*Sardinops sagax*)

Pacific sardine is a shared stock with the United States and is assessed annually by US scientists (DFO 2002h). Pacific sardine was listed as vulnerable by COSEWIC in 1987 and sardine fisheries were closed in BC. Abundance of sardine in BC waters depends on spawn biomass in southern California. After the recovery of the Californian stock, sardine reappeared in BC waters in 1992, increasing through the 1990s to what may be historical levels. There was a limited experimental harvest from 1996 to 2001 and Pacific sardines were de-listed by COSEWIC in May 2002. A commercial fishery started in 2002 (DFO 2004d).

Invertebrates

The term invertebrates encompasses a diverse array of animals that do not have a backbone. Many invertebrates are collectively referred to as "shellfish." These include crustaceans (e.g., shrimp, crabs, barnacles); molluscs (e.g., clams, oysters, snails, squid, and octopus); and echinoderms (e.g., sea urchins, sea cucumbers). There are significant

BC fisheries for crab, shrimp, clams, and other species. The wholesale value of shellfish harvested in BC was $194.8 million in 2004.

Dungeness crab (*Cancer magister*)

Dungeness crabs occur from California to Alaska in shallow, sandy bottom habitats. There are commercial, First Nations, and recreational fisheries throughout its range. It is one of the most valuable invertebrate fisheries in BC, with a wholesale value of $67.9 million in 2004. The commercial fishery uses baited traps fished from vessels in seven license areas. Landings are unknown for the First Nations and recreational fisheries, but may be substantial in some areas. There may be significant unreported or illegal harvest (DFO 2001a). All stocks are intensively harvested and appear to be fully exploited. Catches in all areas are subject to natural variation between years but most fisheries are expected to remain sustainable, despite a high exploitation rate (e.g., DFO 2001a).

Shrimp (*Pandalus* spp. and *Pandalopsis dispar*)

The shrimp trawl fishery lands seven species of shrimp, but the primary target species are smooth pink, northern pink, and sidestripe shrimp. Catches of other species, including prawns, are restricted to smaller quantities. With the sharp decline of fishing effort in the offshore water around 1997 (largely because the drop in the world price paid for shrimp has made the fishery less economical), less than half of the coast-wide catch is now taken from offshore waters.

There is an inshore trap fishery for prawn, coonstripe, and humpback shrimps, as well as a First Nations food fishery. There is also an unlimited entry recreational shrimp trap fishery, operating mostly in easily accessible inshore areas. Commercial, recreational, and First Nations trap fisheries for prawns are considered to be fully sustainable but fully exploited at present effort and participation levels (DFO 2004e).

Clams

- Geoduck clams (*Panopea abrupta*) are among the most valuable invertebrate fisheries in BC. There is a First Nations harvest under communal licence and a recreational fishery limited to hand digging (DFO 2004f). Recent years have seen strong recruitment in geoduck beds over a range of harvest histories (DFO 2000b). The geoduck fishery appears sustainable under the current catch and management framework (DFO 2005a).
- Horse clams (*Tresus capax* and *T. nuttallii*) are harvested incidentally to geoducks and both are harvested by divers using high-pressure waterjet. A pilot directed fishery for horse clams began in 2003 that appears to be sustainable under the current management (DFO 2004f).
- Manila, littleneck, and butter clams (*Venerupis philippinarum, Protothaca staminea,* and *Saxidomus gigantea*) currently support commercial and recreational harvests, as well as First Nations food and ceremonial fisheries. Clams are harvested during low tides using rakes or scrapers. Although other species are taken, the primary target is

Manila clam and the commercial fishery is primarily managed for this species (DFO 1999r). There is concern that intensive harvests and repeated digging may affect survival and growth rates and that the size limit may not be protecting Manila clams against poor recruitment (DFO 1999r). Littleneck clams are assumed to be adequately protected by the size limit and lower fishing pressure because they are less desirable (DFO 1999s). Quotas have been set for some clam fisheries on the coast. The invasive varnish clam may be competing with native clams (DFO 1999r,s).

Other Species

At times there are, or have been in the past, fisheries for the following invertebrate species: goose barnacle (*Pollicipes polymerus*), roe fisheries for green and red sea urchins (*Strongylocentrotus droebachiensis* and *S. franciscanus*), giant red sea cucumber (*Parastichopus californicus*), opal squid (*Loligo opalescens*), neon flying squid (*Ommastrephes bartrami*), krill (*Euphausia pacifica* and *Thysanoessa* spp.), scallops (*Chlamys rubida* and *C. hastata*), northern abalone (*Haliotis kamtschatkana*), and razor clams (*Siliqua patula*).

Interpretation

Published outlooks for assessed fish and invertebrate stocks differ greatly in the types of information presented, so it was not possible to summarize information into tables or graphs for comparison with outlooks for the stocks published in the future. This is not surprising, given the complexity and diversity of the fisheries presented. For species where assessment is done, however, it should be possible to include consistent information in all stock status outlooks. For example, the Food and Agriculture Organisation of the United Nations (FAO) and many regional fisheries agencies report the status of fish and invertebrate stocks according to their level of exploitation (i.e., underexploited, moderately exploited, fully exploited, overexploited, no data; FAO 2005). This information was included in some of the BC stock outlooks, but not for all species. Such categories have the advantage of being trackable through time and they can often be computed with information already being collected for the fishery. Adding consistent categories to published stock outlooks would help interested stakeholders to follow the progress of fisheries management through time.

Nevertheless, the high cost of conducting stock assessments means that it is simply not feasible to perform complete assessments for every species. Fisheries and Oceans Canada is exploring options with industry and First Nations for joint funding and research projects (DFO 2004g). For example, research for the sablefish fishery is now jointly funded and carried out by industry (DFO 2003a). Many invertebrate fisheries are also shifting to this kind of management. For low-value species, however, it may never be financially or logistically feasible to perform proper stock assessments. Abundance of these species will continue to be monitored by data obtained from the commercial fishery.

Supplementary Information: A Herring Tale

Herring is one of the oldest commercially fished species (caught in BC since 1877). The fishery evolved from producing dry salted fish in the early 1900s to a reduction fishery producing fish meal and oil in the 1930s. Currently the main fishery is for herring roe. Herring is also a key forage fish for other fish, and for marine mammals and birds, meaning that the level of abundance of herring can have a ripple effect on the populations of other animals in the marine food web.

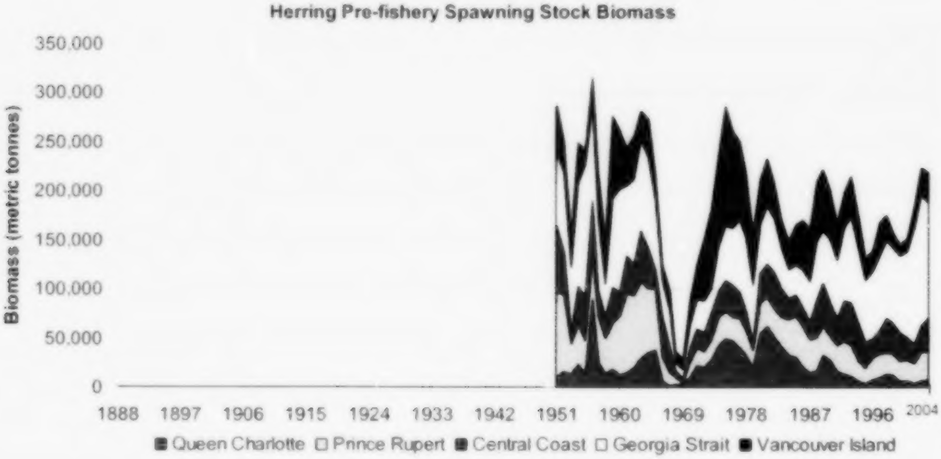
Using herring as an example, the following graphs demonstrate some of the complexity of interactions between fishing pressure and ocean conditions, fisheries management practices and market forces, on both the biomass of the fish population and what is caught.

Using retrospective analytical models, Schweigert (2004) estimated the pre-fishery spawning stock biomass for the five major stocks of herring from 1951–2004 (Figure 4a). Figure 4b shows the catch of herring from the late 1800s to 2004. Herring catches rapidly increased through the early 1960s, mainly in the reduction fishery, which had no limits on the amount of herring that could be used. Figure 4a shows the combined effects of overharvesting and the effects of climate change, which resulted in a population crash in the mid-1960s in the five major stocks (Schweigert 2004). After the collapse of the stocks, the reduction fishery was closed in 1967, and herring populations rapidly rebounded to near historical levels.

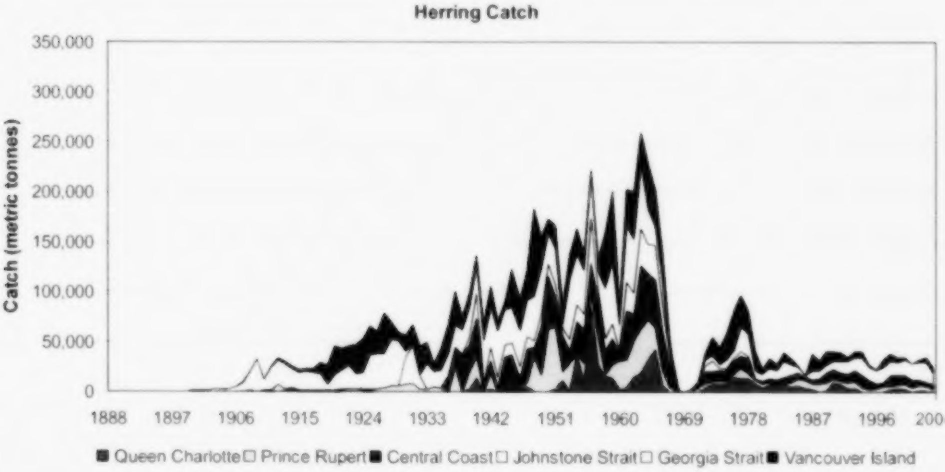
In 1972, stocks were deemed sufficiently robust and a limited herring roe fishery was opened. The fishery is managed conservatively to keep the harvest rate target at 20% of the forecast biomass in each of five management areas on the coast. Although the biomass of most main herring stocks is generally healthy, Figure 4b shows that the catch in the roe herring fishery has declined in recent years. This is predominately because of market conditions in Japan, the main export market (BCMAFF 2004), rather than because of an overall decline in stocks. The pre-fishery biomass graph, however, does show that two stocks (Queen Charlotte Islands and West Coast Vancouver Island) are declining; poor recruitment in these stocks is thought to be linked to climatic conditions.

Figure 4. a. Pre-fishery spawning biomass (in metric tonnes) of herring by spawning stock. b. Time series of herring catch (in metric tonnes) by stock.

a.



b.



Source: Schwiegert 2004 (biomass); and Fisheries and Oceans Canada (catch: *www.pac.dfo-mpo.gc.ca/sci/herring/herspawn/tabcfram.htm*).

4. Secondary Indicator: Change in trophic level of marine catch in Canadian Pacific fisheries

This is an impact indicator. It addresses the question: Have BC marine fisheries shifted toward catching species lower on the food chain?

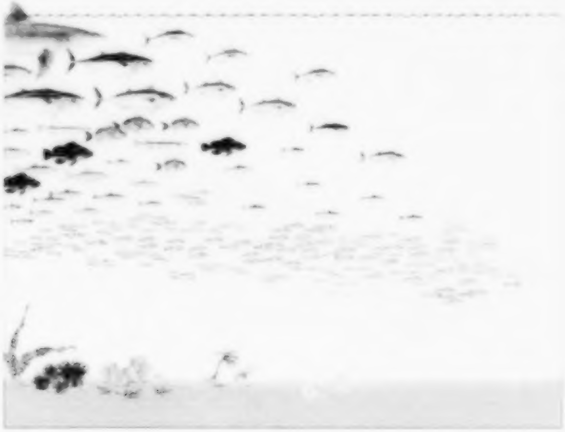
This analysis uses the commercial catch data as a proxy for measuring whether there has been a change in the underlying structure of marine ecosystems. The index does not show the cause of changes, but negative changes would provide an early warning of ecosystem impacts requiring investigation.

Fish populations are embedded within complex ecosystems and interact with other organisms largely as predators, prey, or competitors. The trophic (feeding) role played by a particular species depends to a degree on its size (i.e., larger fish tend to eat smaller fish). This indicator reports the mean trophic level (TL) for Canada's Pacific fisheries. The international Convention on Biodiversity (UNEP 2004) has proposed the mean TL as a global indicator of impacts of commercial fishing on fish stocks. A decline in the index could indicate changes in trophic structure of the ecosystem, possibly caused by unsustainable fishing practices, global climate change, or other factors.

A simple way to think about trophic structure in ecosystems is to arrange trophically linked species hierarchically along a "food chain" (Figure 5). Each link of the simplified food chain is called a trophic level (Lindeman 1942). Trophic levels range from an assigned value of 1 for plants and algae to a value rarely exceeding 5 for top predators, such as marine mammals, large sharks, and humans. The trophic level is calculated by adding 1 to the trophic level of the prey consumed. A fish feeding on algae would therefore have a trophic level of 2; a fish feeding on that fish would have a trophic level of 3; and so on.

This system becomes complicated, however, because many animals feed at several trophic levels and thus cannot be allocated to just one trophic level. To address this, fractional trophic levels are calculated from what is known about the average proportion of each type of prey in the diet of a particular species. For example, a fish that eats 20% algae and 80% herbivores would have a trophic level of $1 + (0.2 \times 1 + 0.8 \times 2) = 2.8$ (see Odum and Heald 1975; Christensen and Pauly 1992).

Figure 5. Illustration of the concept of fishing progressively farther down marine food webs. The blue arrow represents fisheries efforts moving to target lower trophic levels as the upper levels diminish.



Source: Concept by D. Pauly, illustration by A. Atanacio. Reproduced with permission from D. Pauly, UBC Fisheries Centre.

Using trends in the mean TL of fisheries catches as an indicator of the sustainability of a region's fisheries was first proposed by Pauly and Christensen (1995). Pauly et al. (1998) demonstrated a global trend of declining mean trophic levels in fisheries catches, which was also evident at a smaller scale in several FAO statistical regions. This effect, termed "fishing down marine food webs," has been shown in Thailand (Christensen 1998), the Mediterranean (Stergiou and Koulouris 2000), and the North Sea (Furness 2002). For Canadian fisheries, Pauly et al. (2001) reported a downward trend in mean trophic level of landings in east coast Canadian fisheries of approximately –0.1 TL per decade. For west coast Canadian fisheries up to 1996, Pauly et al. found a more complex pattern (see Figure 6), with a linear increase in mean trophic level from 1873 to 1894 (a slope of 0.215 TL per decade), followed by a period up to 1996 with an overall linear TL trend of –0.032 per decade.

A proposed explanation for long-term declines in TL of landings is the result of fishing pressure. Fisheries tend to switch from catching large, predatory species with high trophic levels to shorter-lived species with lower trophic levels as their relative abundance in the ecosystem changes (Pauly et al. 1998). Species with high trophic levels (cod, tuna, and sharks) tend to be less resilient to overfishing and are depleted more quickly than species with low trophic levels (Kirkwood et al. 1994). As the effort to catch these larger species increases, some or all of the fishing fleet will seek new targets. Step-wise declines in the mean TL may occur when new technology enables greater exploitation of a species, followed by collapse of that species and a shift to exploitation of others of lower trophic levels.

Other explanations for observed trends in mean trophic levels of fisheries catches have also been suggested (e.g., Caddy et al. 1998; Caddy and Garibaldi 2000):

- Changes in technology and markets may be stronger driving forces than changes in abundance. Valuable species may be selectively targeted because of high demand. Many crustaceans with low trophic level (e.g., prawns, crab) and molluscs (e.g., scallops, geoducks) fall into this category.
- Similarly, landings of valuable species (e.g., bluefin tuna, Atlantic cod) may remain high even when stocks are depleted because their value makes it worthwhile to meet the costs of continuing to pursue the fishery. For this reason, Pauly et al. (1998) and Pauly et al. (2001) have suggested removal of certain species from the analysis that may "mask" or exaggerate underlying trends.
- In certain systems, there may be a "bottom-up" effect on the food chain caused by eutrophication that kills organisms at the base of the food web. This may lead to a cascade effect on animals farther up the food chain and may be primarily responsible for observations of increased landings of species of lower trophic levels.
- There are well known problems with using commercial catch data as a proxy for underlying system structure, particularly when overfished species undergo range collapse (e.g., see Hilborn and Walters 1992). It is not yet clear how the mean TL is affected by such an effect. Furthermore, the quality of the data used in the analysis will strongly affect the outcome—especially if data are missing or species are too aggregated.

The mean TL is reported here because it has been adopted internationally by the Convention on Biodiversity as an indicator of the integrity of marine ecosystems (UNEP 2004). Within a suite of indicators, it may become a useful indicator of changes in BC marine ecosystems, especially when more fishery-independent data become available. An example of how this indicator could be used comes from a recent study of Celtic Sea fisheries, which found a significant decline in mean TL of both catches and landings. This led to study of a number of factors, in which Pinnegar et al. (2002) concluded that there had been some change in the underlying structure of the system, possibly due to fishing, but that market pressures were not a cause of the observed decline and that long-term climate variability may have contributed to it.

Methodology and Data

Mean trophic levels of landings for each year (Mean TL_y) were calculated by weighting trophic levels of each species according to catch and calculating the mean for each year:

$$\text{Mean } TL_y = \Sigma\,(C_{iy} \cdot TL_i) / \Sigma\, C_{iy}$$

where C_{iy} represents the landings of species *i* in year *y* and TL_i is the fractional trophic level of species *i* (Pauly et al. 1998).

Catch data were obtained from DFO from 1982 to 2003 (S. Spohn, DFO Regional Data Unit, 2004, pers. comm.), except for groundfish trawl fisheries (Option A and B) and sablefish trap and longline data, which were obtained from R. Stanley (DFO PBS, Nanaimo, 2005, pers. comm.)

The data provided by DFO for the years after 1995 represented only catches from five fisheries (bottom and midwater trawls; hook and line; trap; and longline, not including halibut). Catches from salmon gear, seine nets, shore-based invertebrate fisheries and halibut were obtained from DFO's landings statistics website (*www-sci.pac.dfo-mpo.gc.ca/sa/Commercial/AnnSumme.htm*) and added to the data.

Where possible, an attempt was made to use similar trophic level estimates to those used in Pauly et al. (2001) so that a comparison could be made. Specifically, for salmon, a trophic level of 3.8 was used for all species even though Fishbase (a free online database of biological information on the world's fish species: *www.fishbase.org*; Froese and Pauly 2000) gave estimates of 3.5 to 4.4 for the various species. The following estimates were also used, although they may disagree slightly with those found in FishBase: halibut, 4.0; hake, 3.8; Pacific herring, 3.0; all rockfish species where no trophic level was available in Fishbase, 3.4; all tunas, 4.2. In addition, a database of trophic levels was obtained from the UBC Fisheries Centre's Sea Around Us project (*www.seaaroundus.org*, R. Watson, UBC Fisheries Centre, 2005, pers. comm.). For other species where the common name coincided with that given in the Sea Around Us database, the trophic level estimated in that database was used.

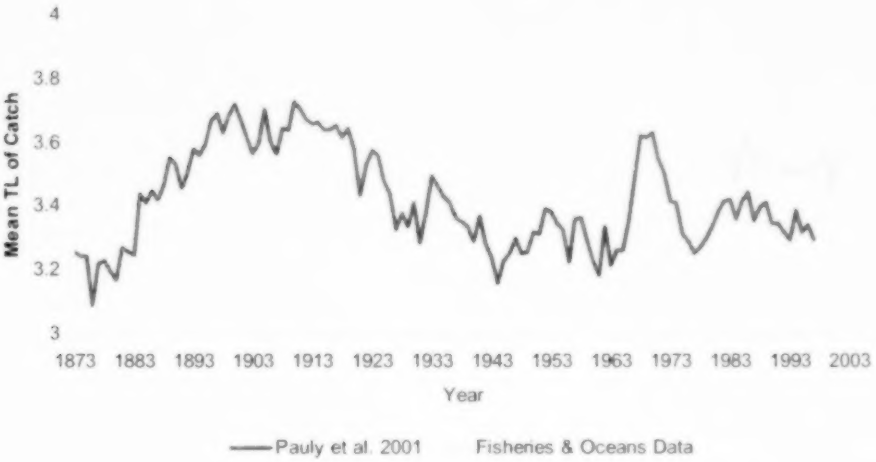
Where no common name was available, estimates from Fishbase were used. For invertebrates, most bivalves, molluscs, echinoderms, etc., were given a trophic level of 2.1; sea stars and other predatory species were assigned 3.5; crabs other than king crab, 2.6; king crab, 2.8; shrimp, 2.7; mammals and birds, 4.0; and fur seals, 4.2 (also after Pauly et al. 2001). Trophic levels for other invertebrates were taken from the Sea Around Us database. Data used for calculation of the Mean TL index in Pauly et al. (2001) were obtained from M.L. Palomares (Fisheries Centre UBC, 2005, pers. comm.). This dataset covers the period 1893–1996, with 15 years of overlap with the DFO data.

The index was calculated using catch (landings + discards), as this represents the underlying ecosystem better than landings alone.

DFO's catch reporting system changed considerably in 1996 with the introduction of Individual Vessel Quotas and mandatory observer coverage. Several discontinuities in the dataset occurred at this time, including the addition of a large number of species that had previously been recorded only under aggregate headings (e.g., after 1996, 32 species of rockfish are recorded that had all previously been reported as just "rockfish"). Although landings of most of these species would previously have been reported under aggregate categories, the extent to which individual species were or were not reported before 1996 is not known. Trends in the Mean TL index before and after 1996 were therefore also calculated separately.

The Mean TL of landings index for west coast Canada, calculated from the historical data of Pauly et al. (2001) as well as from recent DFO catch statistics is shown in Figure 6.

Figure 6. Trophic level of the landings in BC obtained from Pauly et al. (2001) and calculated for this indicator from more recent DFO catch data.



Interpretation

The analysis for this indicator, using recent DFO catch statistics, found virtually no trend in the data between 1982 and 2003 (–0.013 TL per decade), thus no evidence that there has been a detectable change in marine ecosystems. For the period 1982–1995, the linear trend in Mean TL was –0.077 TL per decade. This agrees with the findings of Pauly et al. (2001) of a linear trend of –0.070 TL per decade, for the period overlapping with the present analysis (1982–1996). The difference in magnitude between the two indices is most likely an artefact of changes in estimated trophic levels reported in FishBase.

For the period 1996 to 2003, this analysis showed a trend of +0.059 TL per decade. This reversal of trend is probably not related to changes in the underlying trophic structure of the ecosystem, because it coincides with changes in the reporting system and the resulting dataset, as well as the introduction of vessel quotas and other management measures that would reduce the reported landings of some species. For example, reported catch (landings + discards) of arrowtooth flounder (TL = 4.26) increased by an order of magnitude after 1996, due to increased reporting of discards. Catches of shrimp (TL = 2.7) have declined since 1996, due to the introduction of seasonal closures, catch ceilings and closer monitoring of landings (DFO 1998); this decline is also due to a drop in world prices that has made the west coast shrimp trawl fishery less able to compete economically. The changes in both of these fisheries contributed to the increase in the TL trend observed after 1996, but in neither case does it reflect changes in the underlying structure of the ecosystem.

The value of a composite index, such as the mean TL of landings, depends on the quality of data underlying the analysis. There is a strong possibility that species present in the ecosystem before 1996 were not represented in the analysis because they were discarded and not reported. Also, large changes in fisheries management must be accounted for in the analysis. Although not straightforward to interpret, this indicator is simple to calculate, using readily available data. As a change in the marine ecosystem structure is currently the main hypothesis to explain trends in Mean TL of landings, should a trend be found in future, the likelihood of this hypothesis should be evaluated in light of as much other evidence as is available.

5. Key Indicator: Estimated trends in illegal, unreported, and unregulated (IUU) catch since 1950 in West Coast fisheries

This is a response indicator, showing the effects of changes in regulations and technology intended to address the illegal, unreported, and unregulated (IUU) catch. It addresses the questions: What is being done to mitigate negative impacts of fishing? How successful are these efforts?

In addition to nominal fisheries landings and reported discards, fisheries catches may include a certain amount of IUU catch. There are three components to IUU fishing (see also Bray 2000; Pitcher et al. 2002):

Illegal catch: Catch concealed or misreported as other species in violation of regulatory limits (such as time or area closures, quotas, gear restrictions, licensing, etc.). It may also include unreported harvests landed in foreign ports or trans-shipped to foreign vessels at sea. This is the most difficult component of IUU to quantify. An accurate record is difficult to obtain from surveys if fishers are afraid of incriminating their industry, and the presence of onboard observers is likely to curtail illegal activities altogether during the observation period (e.g., Zwanenburg and Smith 1983; Kulka 1997).

Unreported catch: This includes discards not included in catch statistics (but that may be recorded by observers); fish taken home or eaten by fishers; and recreational catches, which may be significant (e.g., Post et al. 2002).

Unregulated catch: Catches of species that authorities do not have a mandate to monitor or catches originating from vessels or gear types not subject to strict accounting requirements.

In west coast Canadian fisheries, the only IUU component regularly assessed is discards for the groundfish trawl and hook and line fleets. Efforts to quantify discarding through use of on-board observers have been limited to large vessels. Observer coverage for the groundfish trawl is now very high (100% of vessels are covered, but not for 100% of the time); the hook and line fleet receives partial coverage (Haigh et al. 2002).

Quantifying IUU catch is extremely difficult. In the absence of reliable estimates of unreported catch, a "zero" quantity for IUU elements is often assumed (Pitcher et al. 2002), despite the possibility that absence of these records could affect estimates of stock abundance and safe harvest rates. Recently, a new methodology was developed to estimate changes in the quantity of IUU catches over time, based on influences in the history of the fishery and on independent estimates of misreporting (Pitcher et al. 2002; Ainsworth and Pitcher 2005).

Ainsworth and Pitcher (2005) estimated discards and illegal catch for the past 50 years in the major BC fishing sectors: salmon (gillnet, troll, seine, and recreational) and groundfish (bottom trawl, hook and line, and recreational). The results of the analysis are used as a response indicator, by relating relative quantities of estimated IUU catch to the regulatory and technological conditions at the time. To some extent it is also a pressure indicator, as it provides an estimate of one component of fishing pressure on stocks.

Methodology and Data

The following sections summarize the methods and results of Ainsworth and Pitcher (2005). A detailed discussion of the method and results, including underlying data tables used in calculations are available in the published paper.

To estimate missing catch, a technique similar to that reported in Pitcher et al. (2002) was used. The calculations use Monte Carlo statistical methods to mathematically simulate real systems by taking the randomness (probabilities) inherent in real systems into account. Once many simulations are performed, an average is taken from the total number of observations. Monte Carlo simulations are well established as a tool for risk and decision analysis to help make decisions where there are uncertainties in trends, model parameters, and other factors.

The basic methodology follows seven steps:

1. Create a timeline of the fishery, taking note of regulatory, technological, and political changes that are likely to have affected the quantity of fishery discards, illegal, unreported, and misreported catch.

2. Create a running score of "influence factors" describing the effects of each historical event on IUU rates to obtain the estimated trend of IUU through time. For example, quotas are known to sometimes provide incentive to discard less valuable or smaller fish to fill the quota with more valuable fish (e.g., Arnason 1994, 1996). Ainsworth and Pitcher's (2005) analysis considered 154 events in the history of BC fisheries since 1950 that are likely to have affected rates of IUU, including changes in management and policy, and technological and market developments.

3. Assign an "incentive" rating (low, medium, or high), based on the magnitude of influences, to describe the total incentive to misreport for each 5- or 10-year period in the timeline.

4. Scale the incentives trend to establish an absolute range of values for each incentive rating (in units of percentage IUU catch per target species catch). These values are based on fixed "anchor points," which are quantitative, independent estimates of IUU taken from the literature and expert opinion.

5. Estimate absolute IUU for missing periods based on relative incentive rating.

6. Using the range established in step 4, provide an estimate of total extractions for each fishery (reported plus missing catch), weighing the contribution of each gear type to IUU by its mean reported catch. For each period, estimates will contain an upper and lower bound. If possible, determine a "best guess" estimate within the total range.

7. Use Monte Carlo resampling to determine the mean weight of missing catch with associated confidence intervals for each period, based on the likely error range established in step 6. Assume an asymmetric triangular distribution around a specified mode (the "best guess").

In this analysis, IUU categories were considered separately in terms of influences acting on them. An independent history of influences for each type of IUU was developed, based on a review of the relevant literature. Categories of IUU considered were (i) discards; (ii) illegal catch; and (iii) unreported catch. Discards in the salmon and groundfish fleets were assumed to contain both "unreported" and "unregulated" catch.

Discards: Information about discards for the salmon and groundfish fisheries included data from experimental fisheries, onboard observer programs, and predictive models. In some cases, data from outside BC were used. For the groundfish trawl fishery, it was assumed that proportional discard data from the halibut trawl fishery (which has the most information) could be applied.

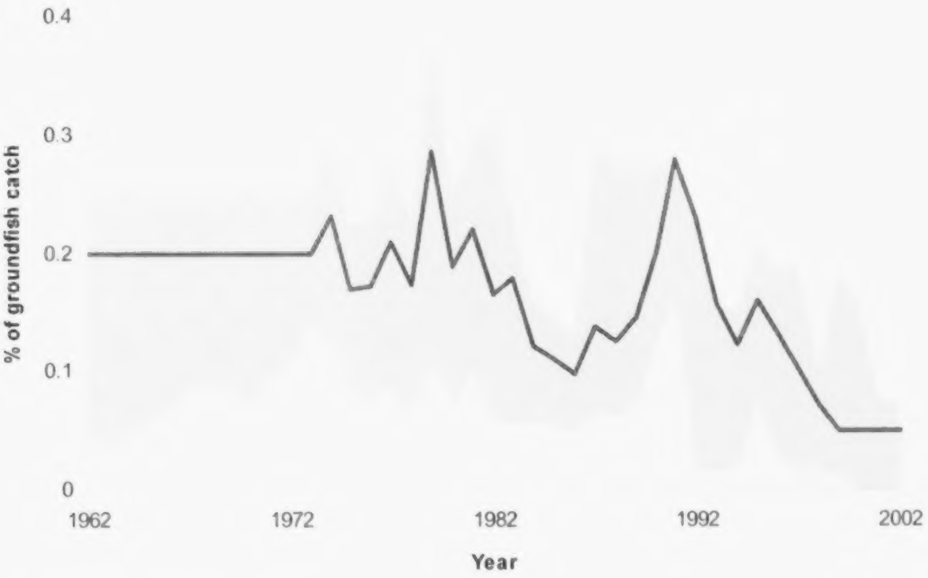
Illegal catch: Fisheries and Oceans Canada publishes news releases detailing the confiscated weight of illegally caught fish taken by fishery officers during enforcement operations. Because the news releases represent a small proportion of total incidences of illegal activity, in the absence of complete information, a critical assumption was made that DFO news releases account for 10% of the total weight of fish taken illegally (including weight confiscated but not reported, and including illegal catch that goes unnoticed by authorities).

Unreported catch: The only "unreported" catch considered by Ainsworth and Pitcher (2005) was that of the recreational salmon fleet. Anchor points were based on the discrepancy between the two available datasets for sport catches in BC. DFO Pacific Region conducts annual creel and logbook surveys (supplemented by aerial observations) to calculate recreational catch. These estimates can represent as little as one-third of the total amount estimated by mail-out surveys, conducted every 5 years by the DFO Statistical Services Branch. The disagreement is likely due to differences in methodology, because the Pacific Region's creel estimates do not account for landings in many ports and do not capture activity on the shore or at private docks.

The nature of IUU catch demands an unavoidably subjective method for quantification. The methodology depends on the reviewed literature and other independent sources to set the range of likely values and therefore makes the major assumption that these sources adequately represent the scope of IUU catches. Other assumptions made the analysis are summarized in Ainsworth and Pitcher (2005).

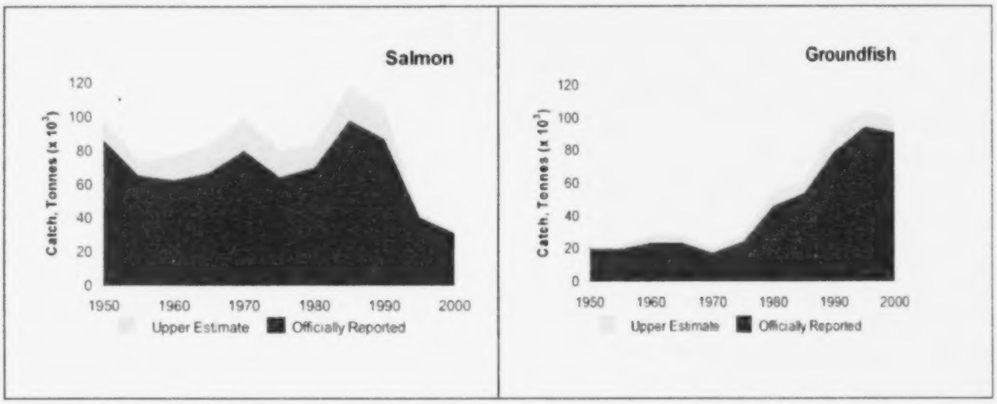
The likely range of groundfish discards resulting from this analysis is shown in Figure 7. Estimated total extractions from the salmon and groundfish fisheries are shown in Figure 8.

Figure 7. Likely range of groundfish discards. Shaded area shows full range of estimates available in the literature; the line shows "best guess" estimate from calculations.



Source: Ainsworth and Pitcher (2005).

Figure 8. Total estimated extractions in BC salmon and groundfish fisheries, 1950–2000. Upper area shows upper estimate of IUU catch at the 95% confidence limit.



Source: Ainsworth and Pitcher (2005).

Results for the three types of IUU are summarized below. For caveats and assumptions, see Ainsworth and Pitcher (2005).

Discards: Discards in the salmon fleet appear to have been small in comparison to reported catch. The highest values found in the published literature were around 5 to 6% of total landings. This analysis suggests that discards were around 2.2% until the mid-1980s, then dropped to the current estimated level of less than 1%. The estimated decrease was related largely to gear modifications introduced in the 1980s (e.g., weedlines in gillnets and brailing boards in the seine fishery) used in conjunction with new techniques to improve selectivity.

At its worst (from 1990–1995), it was estimated that the hook and line groundfish fleet discarded a weight of fish equivalent to 22.6% of reported catch. Between 1975 and 1980 the trawl fleet is estimated to have discarded approximately 17.8% of reported catch. In recent years, however, bycatch reduction initiatives have had an impact. Mesh size regulations, exclusion panels, grates, unhooking techniques, and species-selective baits have been used to reduce incidental capture. Despite a three-fold increase in groundfish landings, the rate of discarding in the groundfish fleet is now estimated to be relatively low.

Illegal catch: Illegal catch appears to have declined in the past decade. Incentives and opportunities to poach in both salmon and groundfish fleets remained stable until the mid-1990s, when observer programs were introduced for several fisheries (Ainsworth and Pitcher 2005). Also, illegal catch that had been occurring in unofficial commercial aboriginal fisheries was legitimized by political changes (e.g., the Sparrow decision; the pilot sales program; Wappel 2003).

Unreported catch: In recent decades, the recreational sector officially accounted for only 8% of salmon landings. For this sector, reporting is usually voluntary and there are large data gaps in the catch record, making estimates of unreported salmon catch significant. Unreported sport salmon catches may have exceeded the official statistics (obtained from creel and logbook surveys) by 220% until the mid-1990s. Since then, unreported catch appears to have been reduced by almost an order of magnitude relative to recorded landings.

Interpretation

IUU catch is estimated to be declining for salmon and groundfish, both in proportion to reported weight and in absolute terms. Between the 1950s and 1980s, 10,000 to 20,000 tonnes of IUU catch is estimated to have been taken in BC salmon and groundfish fisheries, mostly as discards and recreational salmon catch. IUU catch is estimated to have increased throughout the 1980s and, by 1990, the amount was probably closer to 30,000 tonnes per year (equivalent to 18% by weight of recorded landings). By 2000, it is estimated that IUU catch had fallen to about 8000 tonnes per year (6.6% of landings).

Obtaining the estimated trend of IUU through time was key to addressing the question of how successful regulatory efforts have been to mitigate IUU fishing (see Table 7). These sources suggests that, in general, direct regulatory attempts to reduce IUU (e.g., by introducing observers on vessels and improving enforcement) have been most successful, especially in the salmon fleets.

In contrast, regulations that limit the size or quantity of fish that can be landed may have increased incentives for IUU and appear to be related to the higher incidence of IUU in the groundfish fleet. Technological improvements specifically designed to reduce bycatch (e.g., sorting grids) have been successful, whereas those aimed at increasing fishing power (e.g., larger vessels, "rock-hopper" gear that allows trawls to operate on rough ocean bottoms) have tended to increase incidences of bycatch, although these influences appear to be low compared with the effects of various quota systems.

Table 7. Timeline of regulatory and technological changes affecting BC fisheries (see Ainsworth and Pitcher 2004, 2005 for original data sources).

Date(s)	Event
1950-1954	1950: Otter trawls, drum seiners introduced, purse seining mechanized using hydraulic systems. American fleet begins to enter BC waters in numbers. 1952: International North Pacific Fisheries Commission established. 1953: Canada/US Convention for the Preservation of the Halibut Fishery of the Northern Pacific Ocean and Bering Sea signed. 1954: Voluntary trawl logbook program improves collection of catch statistics for Pacific Ocean perch, other rockfish.
1955-1959	c1955: Nylon, polyester used in net construction. Echo-sounders integrated into fleet.
1960-1964	c1960 Larger trawl vessels in use. Spawning channel construction, flow control projects and hatchery programs initiated to improve salmon production. Rockfish fishery begins. 1961: Foreign catch now includes sablefish. Foreign vessels required to carry licence. 1964: Territorial Sea and Fishing Act (international jurisdiction). 1965: USSR fleet enters BC waters. Canadians groundfish trawl begins in earnest.
1965-1969	c1966: Japanese fleet enters BC waters. 1967: Rockfish records begin. Improved technology to preserve fish at sea (e.g., quick freezing). Long-range navigation systems (LORAN) in use.
1970-1974	c1970: Fishers report greater variety of rockfish species (misreporting may have occurred to avoid restrictive regulations). Freezers enable market for less valuable species for use in processed foods (e.g., imitation crab, scallops). 1971: Large area fishery closure in Queen Charlotte Sound to reduce foreign fishing for POP.
1975-1979	c1975: Polish fleet enters BC waters. Average vessel size doubled since 1940, now up to 60 tonnes. Trawl fishery shifts away from POP to other species. 1976: Limited entry to groundfish trawl established using trip limits. 1977: Canada extends fisheries jurisdiction to 200 nautical miles under Economic Exclusive Zone (EEZ). Soviet and Japanese rockfish catches cease. Salmonid Enhancement Program begins. A change in British Columbia Fishing Regulations [1888] prohibits natives from selling catch commercially. Late 1970s: Salmon aquaculture begins in BC on Sunshine Coast and NE coast of Vancouver Island. 1978: Annual quotas applied to groundfish fishery. 1979: Department of Fisheries and Oceans established, implements license limitations, total allowable catches, species/area/time closures and trip limits to control harvest of groundfish.
1980-1984	c1980: Global Positioning System use begins. Rock-hoppers/tickle chains used to reduce habitat damage and bycatch in trawl fleet. Most foreign fishing ends in EEZ. Increasing engine power and fiberglass hull designs for salmon gillnet fleet results in shorter "soak" times and reduces bycatch. 1980: Groundfish trawl advisory committee formed. Vessel trip limits and area quotas imposed on yellowtail rockfish fisheries; quota applied on rock sole. Misreporting and discards in rockfish fishery increase in response to new regulations. 1981: Amendment to BC Fishing Regulations restricts number and species caught by Aboriginal people for food, social, and ceremonial purposes. New techniques improve age determination of major groundfish species.

	1982: US ceases rockfish catch. 1983: Quota for widow rockfish implemented.
1985-1989	1985: Salmon Enhancement Plan integrated into Pacific Region Salmon Resource Management Plan. Fisheries Act introduced, gives DFO authority to close fisheries for conservation. Canada ratifies Canada/US Pacific Salmon Treaty of 1984. 1986: Commercial fishery for widow rockfish begins. 1987: First quota for lingcod introduced. DFO initiates Pacific Regions Fisheries Observer Program to monitor trawl offloading, collect data for research and enforcement; observer coverage contracted for foreign and domestic vessels in EEZ. 1989: Observer coverage extended offshore to seamount fisheries. Late 1980s and 1990s: Salmon prices fall due to increasing aquaculture production, high yields in Alaskan salmon fisheries. Commercial size limit for lingcod increased to 65 cm in Strait of Georgia.
1990	Sparrow decision affirms Aboriginal right to fish under 1982 Constitution Act. Individual transferable quota (ITQ) established for sablefish fishery. Annual quotas for English sole and vessel trip quotas for petrale sole applied. Commercial lingcod fishery closed in area Strait of Georgia. Dockside monitoring with 100% coverage of landings initiated for ITQ sablefish fishery. Weedlines used in gillnet fishery to reduce steelhead bycatch. Use of sorting grids begins.
1991	Joint Canada/US commitment to reduce halibut bycatch through International Pacific Halibut Commission. BC initiates individual vessel quota system for halibut. Voluntary 140 mm cod-end mesh size suggested by 1991 Pacific groundfish trawl management plan for Pacific cod fishery (78 mm mesh size legislated). Dockside monitoring initiated for halibut IVQ fishery Recreational lingcod fishery size limit of 65 cm imposed.
1992	TAC and trip limits imposed on Hecate Strait Pacific cod fishery. DFO cooperates with Department of National Defence to conduct air surveillance patrols of North Pacific looking for high seas drift netting. Canada/US salmon agreements under the 1984 Pacific Salmon Treaty expire leading to competitive harvesting. Aboriginal Fishing Strategy established in response to Sparrow decision. Pilot Sales Program permits limited commercial catch for natives to reduce poaching. DFO issues permits for commercial aboriginal salmon fisheries in Port Alberni, Lower Fraser R., Skeena R. under the Aboriginal Fishing Strategy. 1992 Fraser R. sockeye fishery an "environmental disaster"; Pearse-Larkin report commissioned to investigate link to AFS. Pacific license retirement plan initiated.
1993	North Pacific Fisheries Commission dissolved, replaced by Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean. Sustainable Fisheries Program launched by DFO to conserve Skeena R. salmonids, includes steelhead observer program. Previously unrestricted widow and canary rockfish receive coast-wide quotas and trip limits. Quota for lingcod introduced. Aboriginal Communal Fishing Licenses Regulations approved.
1994	Misreporting reduced by mandatory dock-side monitoring program now in place for majority of groundfish trawl fisheries. UN Law of the Sea enters into force (ratified by Canada 2003).
1995	Directed fishery for petrale sole discontinued coast-wide. IPHC regulation requires halibut to be dressed before offloading, allows halibut bycatch in Pacific cod and sablefish fisheries to be kept. Staged reduction of halibut trawl bycatch mortality. Mesh size regulation for rock sole fishery to minimize juvenile mortality. 140 mm mesh size for Pacific cod trawl fishery now legislated. Under 1992 Pilot Sales Program, commercial licenses granted to three lower mainland First Nations bands on lower Fraser River. UN Food and Agriculture Organization draft "Code of Conduct for Responsible Fisheries," adopted by Canada. Groundfish trawl fishery suspended mid-season (TAC exceeded), hook and line limited. Voluntary buy-back of commercial fishing licenses announced. To improve data collection, BC Sport Fishing Regulations prohibits on-sea canning. Restrictions on west coast Vancouver Island, Strait of Georgia coho stocks due to conservation concerns.
1996	New sport fishery limits introduced for many previously regulated species; higher fines for offences under BC Sport Fishing Regulations. Canada Oceans Act passed: recognizes Canada's ocean jurisdiction, guidelines for integrated management and consolidates federal

	fisheries responsibilities. Amended coastal fisheries protection regulations require foreign fishing vessels to notify DFO on passage through BC waters. New aerial surveillance pilot project augments DFO's enforcement capabilities, improves collection of commercial fisheries effort statistics. Public consultation begins for groundfish IVQ allocations. IPHC increases recreational halibut limit in Strait of Georgia, prohibits halibut fletching (filleting) at sea. Lingcod size limit increased from to 65cm near Queen Charlotte Is. and west coast Vancouver Is. Trawl catch for Pacific cod in Hecate Strait limited to bycatch only, IVQs implemented. IVQs implemented for dover sole (replace area quotas) and English sole. New Groundfish Management Plan includes mandatory on-board observer program for groundfish trawl (replaces limited observer program of 1987) and caps on bycatch for trawlers. IVQ scheme stimulates large increase in the number of active trawlers (probably increasing illegal sales and high grading practices). BC government places 6 year moratorium on new salmon aquaculture (net pen) operations.
1997	Major changes to groundfish trawl regulation sets comprehensive IVQ scheme for 25 groundfish species; allocates IVQ holders 80% of TAC (formalized 1998). Pacific halibut management plan reallocates halibut IVQ. Groundfish Development Authority (GDA) formed to protect non-quota shareholders. Limited entry established for groundfish hook and line. Delgamuukw decision affirms Aboriginal right to fish commercially. Quota for lingcod introduced. Large decline in salmon prices due to expansion of aquaculture, particularly in Norway and Chile. Retention/possession of coho, chinook and steelhead disallowed for all seine fisheries.
1998	Industry develops Canadian Code of Conduct for Responsible Fisheries under new Pacific Fisheries Adjustment and Restructuring Program. Selective Fishing Program initiated by DFO: 5% of salmon TAC allocated to improve selectivity; experimental fisheries authorized for data collection and aboriginal fisheries using fish wheels, weirs, beach seine, and other methods; gear modifications to reduce coho bycatch mortality mandated through licensing conditions 1998-2002 (includes: revival tanks; shorter nets and soak times for gillnetters; brailing with dip nets for seiners, knot-less mesh to reduce abrasion, plastic escape holes to release undersized fish; barbless hooks for trollers); this reduces coho bycatch mortality from 60% to 5%. New Coho Response Team seeks new methods to reduce bycatch. Fisheries Renewal BC established to coordinate resources for habitat enhancement under Pacific Salmon Endowment Fund and Pacific Salmon Treaty. IPHC issues new halibut logbooks to improve in-season data collection. DFO and BC Wildlife Federation create first fishery officer-dog team trained for fisheries enforcement. 10% observer coverage implemented for lower Strait of Georgia commercial troll fleet. DFO releases "A new direction for Pacific Salmon Fisheries," reinforcing commitment to developing selective fishing. BC Fisheries Survival Coalition organizes large protest fishery on Fraser R. to protest native-only fisheries.
1999	DFO pilots satellite technology to collect real-time catch data, also biological, oceanographic data. Groundfish trawl fleet now composed of 142 licensed vessels, of which ca. 88 recorded landings. DFO observer program extended to hook and line halibut fisheries and rockfish fisheries. Rockfish Protected Areas implemented and rockfish discarding prohibited. Size limit for recreational lingcod increased to 65 cm off West Vancouver Island. BC recreational fishers required to supply catch records. Joint Canada/US commitment to restore salmon habitat, improve management under 1985 Pacific Salmon endowment funds totalling $200 million CDN established. Additional selective fishing experiments in Juan de Fuca Strait. Supreme Court Marshall decision affirms rights of Maritime aboriginal groups to fish in pursuit of "moderate livelihood." Canadian Environmental Protection Act passed, includes additional marine protection provisions and addresses land-based marine pollution concerns.
2000	Nis'ga treaty ratified, includes exclusive aboriginal fishing rights. Groundfish trawlers accept voluntary area closures to protect Hexactinellida sponge reefs. Environment Canada announces National Programme of Action to reduce land-based marine pollution in response to UNEP Global Plan of Action. Additional DFO funding strengthens fishery enforcement.
2001	UN Fish Stocks Agreement ratified by Canada in 1999, goes into effect. DFO extends observer coverage to all groundfish hook and line fisheries. IPHC allows limited filleting of halibut while at sea. To aid data collection, halibut fishers keep log books throughout season, rather than surrendering books at each off-loading. Race Rocks established as Canada's first Marine Protected Area under Oceans Act.
2002	Moratorium lifted, permits for new Atlantic salmon net-pens issued. DFO announces Rockfish

	Conservation Strategy, including planned Rockfish Conservation Areas, which are extension of Rockfish Protected Areas. Pacific Scientific Advice Review Committee (PSARC) document reports unfavourable lingcod recovery, therefore commercial closure maintained for Strait of Georgia, recreational closure commences. Fraser River coho listed as "endangered" by the Committee on the Status of Endangered Wildlife in Canada. Coast-wide commercial fishery closure for sablefish. Areas surrounding Hexactinellida sponge reefs closed to commercial trawling by annual regulations and area under review for designation as Marine Protected Area. Fisheries Renewal BC ceases operation.
2003	Species at Risk Act (SARA) comes into effect. Green/shortnose sturgeon and Bocaccio rockfish listed as "threatened" by SARA. Pink Salmon Action Plan began in Broughton Archipelago to address poor returns at north end of Vancouver Is., including investigation of mortality factors, such as sea lice infections.

Source: Ainsworth and Pitcher 2004, Appendix Table A.1.

6. Secondary Indicator: Trends in discards in trawl fisheries since the introduction of mandatory observer coverage

This is both a response indicator, showing the effects of management measures to mitigate discards, and a pressure indicator, showing a type of fishing pressure on non-target species. It addresses the question: How effective are efforts to reduce impacts on non-target species from commercial fishing?

Bycatch, discards, and incidental mortality are terms frequently discussed in fisheries as sources of unnecessary fishing mortality. These term are often used interchangeably, which is confusing. In a global study of bycatch, Alverson et al. (1994) provided the following definitions:

- Target catch: The catch of a species or species assemblage which is primarily sought in a fishery, such as shrimp, flounder, cod.
- Incidental catch: Retained catch of non-targeted species.
- Discarded catch: That portion of the catch returned to the sea as a result of economic, legal, or personal considerations.
- Bycatch: Discarded catch plus incidental catch.

The term "bycatch" is still used by some to imply discards, which is appropriate for species that are clearly not targeted (such as seabirds, turtles, or marine mammals). In multispecies fisheries, however, the term bycatch leads to confusion when applied to fish, because many "non-target" species are marketable and are landed. In this case, "discarded" is a better term.

Discarding is a problem because it is wasteful and causes unnecessary fishing mortality. It occurs because fishers may discard fish for which there is no market; that are below minimum size limits; that exceed quota; that exceed carrying capacity of the hold; or that are damaged or undesirable for other reasons. A particular form of discarding, known as "highgrading," occurs when fishers seek only the most valuable fish and discard less valuable, but marketable, individuals.

Of particular concern is bycatch of inshore rockfish (DFO 2004g). For species for which there are conservation concerns (e.g., inshore rockfish, inshore lingcod, petrale sole), targeted fishing has been banned in many areas in BC because bycatch (either landed or discarded) may be a serious impediment to the recovery of such populations.

After extensive consultation with the Groundfish Trawl Advisory Committee, Fisheries and Oceans Canada introduced new management measures in 1996. Key changes were the introduction of Individual Vessel Quotas (IVQs) for all vessels and the introduction of mandatory at-sea observer programs. The Integrated Management Plan for the groundfish fishery (DFO 2004g) states that catch (both retained and released) at-sea will be determined using mandatory observer coverage. There is 100% at-sea observer coverage for Option A vessels, which fish by bottom trawl and midwater trawl in all areas except the Strait of Georgia. There is 10% at-sea observer coverage for the mid-water hake fisheries and for the small Option B fishery, which fishes only by bottom trawl in the Strait of Georgia.

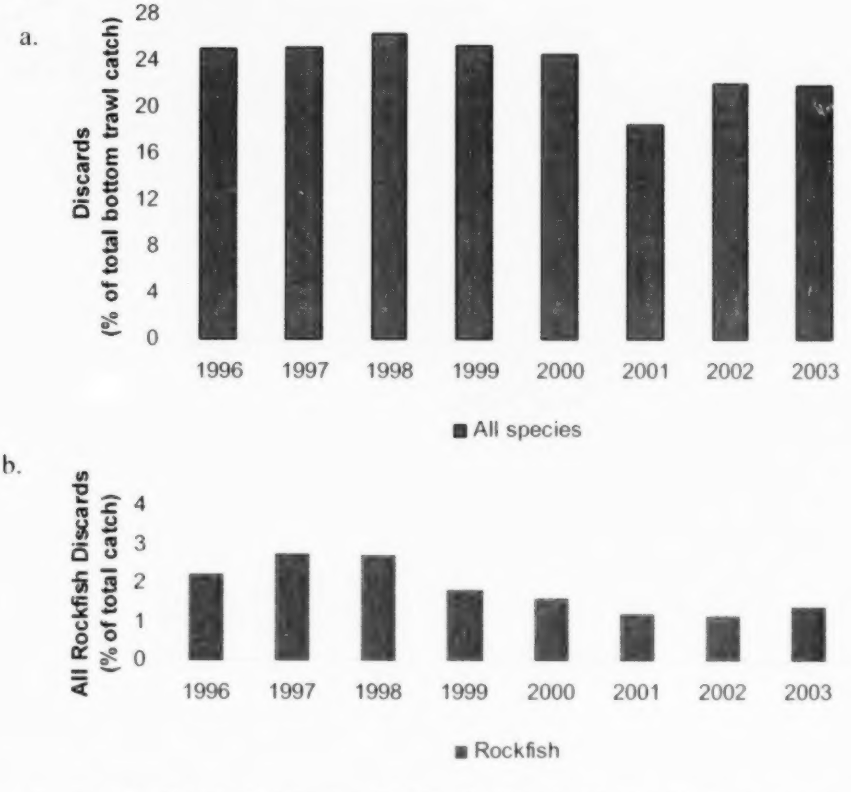
Methodology and Data

Data for this indicator came from information collected by observers on large trawlers. When observer coverage began in 1996, the number of species reported by fishers was approximately 80; this number has increased to approximately 200 species. Additional data are collected through the dockside monitoring program and fishers' logbook programs. Both sets of data are currently kept by Pacific Biological Station, Nanaimo (DFO, Alan Sinclair, Rick Stanley) and include only data for the larger (Option A) trawlers that have 100% observer coverage.

Figure 9a shows discards of all species and of all types of rockfish (including Pacific Ocean perch) as a proportion of total catch (landings plus discards). Figure 9b shows discards and landings of three species of inshore rockfish. There were no discards reported for the other inshore rockfish species.

A closer analysis of the data for the Option A bottom trawl fishery shows that, in total, 143 species were recorded as discarded by the fishery, most in small quantities. Species contributing most to the discarded tonnage were arrowtooth flounder (24,673 tonnes), spiny dogfish (8786 tonnes), spotted ratfish (5741 tonnes), Pacific halibut (3609 tonnes), sablefish (3301 tonnes), Dover sole (2497 tonnes), Rex sole (2149 tonnes), big skate (1849 tonnes), English sole (1733 tonnes), and rock sole (1485 tonnes) (all totals are since 1996).

Figure 9. a. Proportion of total catch (landings plus discards) of all species discarded by Option A trawlers in BC. b. Proportion of total catch (landings plus discards of all species) of all species of rockfish discarded by Option A trawlers in BC. Rockfish species include Pacific Ocean perch. Note different scales.



Source: Alan Sinclair, Rick Stanley, DFO Pacific Biological Station, Nanaimo, pers. comm.

Interpretation

Percentage discards of all species have declined slightly since the introduction of IVQs and mandatory observer coverage (Figure 9). Approximately 25% of the total catch was discarded in 1996. This figure declined to a low of 18.5% in 2001, then rose again to 22% in 2003.

Percentage discards of rockfishes have also declined from 2.7% in 1997 to 1.4% in 2003 (Figure 9b). It was not possible from the data to determine the cause of the declines, which may be due in part to more selective fishing practices, but also may be due to declines or reduced catchability of some species. With the present data, it is difficult to draw conclusions about reasons for the observed trends in discarding by the bottom trawl fishery.

In future, Fisheries and Oceans Canada has committed to monitoring the discards of all species in its Integrated Fisheries Management Plan. DFO will begin to require full observer coverage and electronic monitoring in 2006 for commercial groundfish fisheries. When fully implemented, all fish will be counted, including discards, and fishers will have to have enough individual quotas to cover the estimated mortality from discards. This program is expected to provide further incentive to reduce discarding.

Supplementary Information: Other Incidental Fishing Mortality

Fisheries can cause unintentional mortality to non-target species through accidental deaths from collisions with fishing boats, entanglement with fishing gear, and continued "ghost fishing" by lost gear. Ghost fishing has been listed as one of the issues to be addressed under the Canadian Code of Conduct for Responsible Fishing Operations, a set of protocols developed by the fishing industry and Fisheries and Oceans Canada to meet international obligations for sustainable fishing.

Whale entanglement: Accidental catch of whales in fishing gear is not as much of a problem in BC as it is on the East Coast. Most of the problems in BC occur with gray whales and humpbacks because of their coastal habits. Most gray whales stay within 2 km of shore and are most commonly entangled in crab gear. A recent study to quantify mortality of gray whales in Canadian waters estimated 20 collisions a year with fishing gear, killing an average of two whales per year (Baird et al. 2002).

Humpback whales become entangled in crab gear but are more likely to get caught in gillnets in the inlets (J. Ford, Fisheries and Oceans Canada, pers. comm., 2005). Entanglement incidences with humpback whales have increased in recent years, likely due to an increase in their number.

"Ghost" fishing: Removal of animals from a population by lost fishing gear is an issue in fisheries that uses passive gear such as traps or gillnets (Breen 1990). When traps or nets are lost, they may keep fishing for many years until the gear rots or becomes so overgrown by animals or algae that it no longer catches fish. Trapped animals die of starvation or injuries, becoming bait themselves for other individuals. The species most likely to be affected by ghost fishing are those originally targeted by the gear (Brown et al. 1998).

Breen's 1987 analysis of ghost fishing in BC's Dungeness crab trap fishery estimated a trap loss rate of about 11%, resulting in 2,861 traps lost annually; 53% of those traps were estimated to be ghost fishing for an average period of 2.2 years, causing the death of 9.3 crabs per year. This gave an estimated total mortality of approximately 31,319 crabs per year (Breen 1987, summarized by Poon 2005).

Seabird bycatch: Incidental catch of seabirds by hook and line fishing gear is a worldwide concern. Birds are attracted to fishing boats and may be killed either by trying to take bait and becoming hooked and drowning, or by collision with fishing gear. Of primary concern in BC are the short-tailed albatross (*Phoebastria albatrus*), black-footed albatross (*Phoebastria nigripes*), and Laysan albatross (*Phoebastria immutablis*). The short-tailed albatross was listed as Threatened by COSEWIC in 2003, with incidental catch in longline fisheries listed as a major potential threat. No incidental catches of this species have so far been reported in BC. Black-footed albatross is, however, regularly caught in BC (COSEWIC 2003b).

The Integrated Fisheries Management Plans for the hook and line fisheries for halibut and rockfish and other species state that Canada is committed to reducing the incidental mortality of seabirds by longline fisheries. Fisheries and Oceans Canada requires mandatory seabird avoidance measures in the 2005/2006 commercial longline fisheries (DFO 2004b,h,i,j).

WHAT IS THE STATE OF BC FISHERIES?

This question is only partly addressed by the indicators in this paper. These indicators were chosen from a larger field of indicators to provide an overview of the state of West Coast marine ecosystems and fisheries. Although they were defined through a long process of discussion and review, the final choice of what to report was ultimately constrained by the data available. These indicators are being presented as the basis for a suite of fisheries indicators that will be improved upon in future reporting.

Overall, the indicators in this paper show that, although there are conservation concerns for some populations or stocks of fished species in BC, many appear to be doing well.

- An estimated 81% of the salmonid populations in BC (outside of Strait of Georgia) and the Yukon, are at no risk or have a low risk of extinction. Stock assessment outlooks for 2004 classed about half (49%) of managed salmon stocks as stable, increasing, or well above target abundance.
- Other important commercial species, such as Pacific halibut, Pacific ocean perch, Pacific hake, geoduck clam, Dungeness crab, and herring, among others, have levels of abundance sufficient to sustain current harvest levels. Although many groundfish

species are considered to be fully exploited, this does not necessarily mean they are in danger; it does mean they warrant cautious management.

- An international indicator of marine ecosystem structure, calculated for Pacific commercial fisheries, showed no trend in the trophic levels of fish caught since 1982. This means that there was no visible indication of changes in the structure of underlying marine ecosystems according to this measure, whether from fishing or other pressures.
- Estimates of the impact of regulatory and technological changes on reducing illegal and discarded catch in the salmon and groundfish fisheries showed that the regulations have had a positive effect.

Indicators highlighted areas of concern, including:

- Lower Mainland steelhead trout, with all assessed stocks classified as of conservation concern or extreme conservation concern.
- Stock assessment outlooks for 2004 classed 13% of managed salmon stocks in the category of greatest concern. Other research on salmonid populations found that just over 13% of BC and Yukon populations were either extinct (2%) or at the highest risk of extinction. Three Pacific salmon stocks (interior Fraser coho, Sakinaw and Cultus lakes sockeye) have been listed by COSEWIC as Endangered (COSEWIC 2002, 2003a).
- Many inshore rockfish species are at low abundance levels or are experiencing poor recruitment, and 89 areas were closed to fishing at the time of writing. Fisheries are closed for Bocaccio (listed as Threatened by COSEWIC), inshore lingcod (stocks are rebuilding and may be reopened in the near future), Fraser River eulachon, and Northern abalone (listed as Endangered), among others.

Marine ecosystems are complex and difficult to observe. Determining definitive causes for observed changes, whether positive or negative, is rarely straightforward. Poor recruitment during the 1990s was cited as a factor in the decline or low abundance of many species discussed in this paper. This may be caused by overfishing and/or by ocean conditions unfavourable for recruitment. Poor oceanic survival is cited as a reason for the decline in steelhead stocks and some salmon stocks. Climatic "regime-shift" events, such as the Pacific Decadal Oscillation, have been proposed as forces affecting abundance of many commercial species (e.g., Beamish et al. 1997, 1999; Mantua et al. 1997), and may presage the type of changes resulting from global climate change.

Globally, there is concern that fish stocks are not being fished sustainably (e.g., Pauly et al. 2002; Schiermeier 2002). This concern is driven, in part, by collapses of major fish stocks such as the Peruvian anchoveta and northwest Atlantic cod (Ludwig et al. 1993; Walters and Maguire 1996). There is a growing awareness that fisheries are embedded in complex marine ecosystems that may be directly or indirectly affected by fishing pressure (e.g., Hall 1999; Pikitch et al. 2004). The effects of overfishing can rarely be completely excluded as a cause of population decline in fished populations, even when correlations with climatic events exist (Walters and Collie 1988). For example, in BC, during the

1980s and early 1990s salmon and groundfish fisheries were overcapitalized and stocks, such as inshore rockfish, lingcod, and some salmon stocks, were overfished as a result.

The famous "Thompson-Burkenroad debate" of the 1950s about causes of population trends in Pacific halibut (see Hilborn and Walters 1992, p.53) illustrates the difficulty in separating effects of the environment from fishing, even with some of the best data in the world. Both sides of the debate provided compelling evidence for observed cyclic behaviour of halibut populations: one citing cycles in oceanic conditions that affected juvenile survival, and the other citing overfishing as the cause of declines in abundance and reduced fishing, after years of low abundance, as the cause of recovery.

WHAT IS BEING DONE ABOUT IT?

Progress in two major areas of human impact on marine ecosystems—climate change and designation of marine protected areas—are covered in other papers for the Coast and Marine Environment project. With respect to the impacts of fishing, recent national and international efforts to ensure that fisheries are managed sustainably are listed below:

- Since 1996, a large number of changes have been introduced into the management of BC fisheries to address concerns about fleet overcapacity and conservation. The generally positive effects of such changes were reported in the Key Indicator 5 on estimated trends in IUU catch. Although Fisheries and Oceans Canada has worked with the commercial fishing industry for decades, the last decade has shown highest level of cooperation between it, First Nations, and the commercial and recreational fishing industries in Integrated Harvest Planning committees. For example, Integrated Fishery Management Plans for groundfish have been developed with advice from the Commercial Groundfish Integrated Advisory Committee, a stakeholder committee with broad representation. The management plan for the groundfish trawl fishery outlines a sustainability strategy for inshore rockfish, including reducing bycatch, improving catch monitoring, and other steps to ensure a sustainable fishery (DFO 2004g).
- Canada's Policy for Conservation of Wild Salmon was published in May 2005 by Fisheries and Oceans Canada. The stated goal of the Wild Salmon Policy is to restore and maintain healthy and diverse salmon populations and their habitats. It provides for incorporation of information on ecosystems and ocean climate impacts in annual assessments of salmon abundance.
- Canadian Code of Conduct for Responsible Fishing Operations: In response to growing concerns over global depletion of fish stocks, the United Nations Food and Agriculture Organization (FAO) developed a Code of Conduct for Responsible Fisheries. The code was adopted by 80 countries, including Canada, at the 28th conference of the FAO in 1995. The Canadian fishing industry took the lead in applying the international code by developing the Canadian Code of Conduct for Responsible Fishing Operations in 1998. The code contains a set of protocols developed by the fishing industry and Fisheries and Oceans Canada to meet international obligations to promote conservation-based harvesting practices. To date,

more than 60 Canadian fisheries organizations, representing 80% of the landings, have ratified the Canadian code. This means they volunteer to take appropriate measures to ensure fisheries are harvested and managed responsibly. (See *www.ncr.dfo.ca/communic.fish_man/code/eng/con_eng.htm.*)

- The Pacific Fisheries Resource Conservation Council was created as an independent organization to advise the governments of Canada and BC, as well as the public, on the conservation and environmental sustainability of Pacific salmon stocks and their freshwater and ocean habitat. The Council prepares reports on wild salmon stock, salmon aquaculture, fisheries management policy, and recently sponsored a conference to address the impact of climate change on BC fish stocks and implications for fisheries management. (See *www.fish.bc.ca/*; PFRCC 2002.)
- The Marine Stewardship Council (MSC) was established in 1997 with the goal of promoting sustainable marine fisheries by certifying and labelling products from fisheries that use environmentally, socially, and economically viable practices. It has developed a wild fisheries certification standard consistent with the FAO guidelines for ecolabelling of fisheries and operates an accreditation program for independent certification bodies that do the assessments. As of 2005, 12 fisheries in the world have been granted MSC certification. By the end of 2005, 20 more were in the process of assessment for certification, including the BC salmon fishery and Canada's Pacific halibut fishery. Although concerns have been raised that MSC grants certification based on intent to improve methods, rather than waiting until the fishery has met requirements (e.g., Pearce 2003), MSC defends its certification standard as a pragmatic step that will achieve the desired changes. As more fisheries are assessed and consumer awareness of ecolabelling and certification standards increases, such certification programs are a way to support sustainable fisheries. (See *www.msc.org/*)
- The BC Pacific Salmon Forum was appointed by the Premier of British Columbia in 2004. It consists of seven appointed members who are charged with examining the issues surrounding the wild and farmed salmon in BC and making recommendations to the province based on their findings. The forum is intended to generate balanced advice for managing the salmon resource based on the results of scientific research. (See *www.pacificsalmonforum.ca/*)

WHAT CAN YOU DO?

In terms of individual actions, consumers can become informed about fisheries conservation issues and can make an effort to support sustainable fishing practices by purchasing seafood products that come from fisheries with good environmental practices. Sources of such information include:

The Pacific Fisheries Resource Conservation Council: (*www.fish.bc.ca*) The Council website carries online reports as well as information for teachers and students on a wide range of issues related to conservation and environmental sustainability of Pacific salmon stocks.

The Marine Stewardship Council: (*www.msc.org/*) Look for seafood products that are MSC certified and labelled as products from fisheries using environmentally and socially viable practices.

Ocean Wise: (*www.vanaqua.org/conservation/oceanwise/faq.html*) Closer to home, the Vancouver Aquarium launched the concept of Ocean Wise in January 2005. Ocean Wise is a conservation program created to help local restaurants and their customers make environmentally friendly seafood choices. Participating restaurants aim to present a completely sustainable menu and can display an Ocean Wise symbol on their menus. Sustainability of each species that is harvested for seafood is evaluated individually, using information on individual fisheries from the Vancouver Aquarium's own fisheries research, as well as other research from BC and Canada.

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GLOSSARY

Adsorption: A process in which solids or liquids attract and hold other solids, liquids, or gases in a surface film, without chemically combining with them.

Alien species: A plant or animal that has been introduced by humans to a location outside its native range. Also called introduced, non-native, exotic, and invasive species.

Anadromous: Animals that must ascend rivers and streams from the sea in order to breed.

Aquaculture: The controlled cultivation and harvest of aquatic animals or plants, such as finfish (e.g., salmon), shellfish (e.g., clams, oysters), and edible seaweeds.

Ballast water: Water carried by a ship to improve its stability when it is lightly loaded. It is normally discharged into the ocean when the ship is loaded with cargo.

Baseline Thematic Mapping (BTM): A digital integration of satellite imagery and land-use, land-cover, and topographic data to produce an "image map" with contour lines and vector planimetry information.

Bathymetry: The depth of water in the ocean as it relates to the topography or features of the ocean floor.

Benthic: Organisms that live on or in the sediment at the bottom of aquatic ecosystems such as lakes, rivers, and the ocean.

Bioaccumulation: An increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living things if they are taken up and stored faster than they are broken down or excreted.

Biodiversity: The variety and abundance of life, including ecosystems, communities, and the genetic composition of species. Also called biological diversity.

Biogeoclimatic Ecosystem Classification (BEC): A classification system in British Columbia that distinguishes terrestrial zones based on climate, soils, and dominant vegetation.

Biological controls: Using natural enemies of a particular species, usually predators and pathogens, to control population.

Biomagnification: The process that results in the accumulation of a chemical in an organism at higher levels than are found in its food. It occurs when a chemical becomes more and more concentrated as it moves up through a food chain.

Blue listed species: A species classified by the BC Conservation Data Centre as not immediately threatened but of concern because of characteristics that make it particularly sensitive to human activities or natural events.

Biological oxygen demand (BOD): A measure of the amount of oxygen required for bacteria to break down organic matter (e.g., sewage effluent) in water. If BOD is too high, fish and other aquatic organisms are deprived of the oxygen they need for survival.

By-catch (fishery): Discarded catch plus incidental catch. Discarded catch is the portion of the fishery catch that is returned to the sea because of economic, legal, or personal considerations. Incidental catch is retained catch of non-targeted species.

Carcinogen: A substance that may cause cancer in animals or humans.

CCCMA: Canadian Centre for Climate Modelling and Analysis (located at the University of Victoria).

CDC (BC Conservation Data Centre): The provincial government office that tracks species and ecosystems that are in some danger of disappearing from British Columbia. The CDC annually publishes the provincial red and blue lists.

Certification (of products for sustainability): A process whereby an independent, third-party auditing body conducts an inspection and awards a certificate using independently developed standards and objectives.

Chart datum: The Canadian Hydrographic Chart Datum (CHCD) is the lowest tide that can be expected in a given locality considering gravitational effects alone. Even lower tides may occur rarely if strong or persistent winds and storm surges work to further lower the water. The chart datum is used as a reference point for measuring water level at tide gauge stations on the coast.

CO_2 equivalent: The amount of CO_2 that would cause the same effect as a given amount or mixture of other greenhouse gases.

Congener: A term in chemistry that refers to one of many variants or configurations of a common chemical structure. Although similar, congeners may have different toxicological properties and fates in the environment.

Conservation covenant: A legal agreement that specifies the ways in which a piece of land can be used. A conservation covenant is incorporated into the land deed and protects the land in perpetuity.

Conservation: The protection of wild species and their ecosystems.

Contamination: Substances, including those found naturally, that are present at concentrations above natural background levels, or whose distribution in the environment has been altered by human activity.

Corridor: An area of intact habitat that allows wildlife to move in relative safety from one place to another.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada): A national committee of experts that assesses and designates which wild species are in some danger of disappearing from Canada.

Critically Endangered: IUCN classification for a species for which the best available evidence shows that it is facing an extremely high risk of extinction in the wild.

Dioxins and furans: Two families of chlorinated organic compounds that can be formed as by-products of activities such as pulp bleaching and waste incineration. Both can persist in the environment for many years and some forms are highly toxic.

Disturbed environment: Alteration of part or all of a living community from natural or human activity. Storms, landslides and El Niños are examples of natural events; clearcutting, pollution, and harbour dredging are examples of human-caused disturbance.

Ecoregion Classification: A classification system in BC that describes areas of the province with similar climate, physical land and water features, vegetation, and wildlife potential. The classification has five levels from broadest to narrowest: ecodomain, ecodivision, ecoprovince, ecoregion, and ecosection. See Demarchi 1996 for more details. See also, Marine Ecosystem Classification.

Ecosection: The finest scale in the Ecoregion Classification system. Forty ecosections make up the coastal and marine region of BC.

Ecosystem: Plants, animals, and the physical environment (water, air, soil, etc.) interacting in a given area.

Ecotourism: Nature-based tourism that is ecologically sustainable.

Ecotype: A subgroup within a species that has developed distinct physical or behavioural characteristics in response to its local environment that persist even if individuals are moved to a different environment.

Endangered: A species facing imminent extirpation or extinction very soon (COSEWIC).

Endemic: A species native to, and restricted to, a particular geographical region.

Endocrine: System of the body that releases hormones into the blood stream or lymph system. These hormones control growth, metabolism, mood, and reproduction and influence almost every cell and organ in the human body.

ENSO: El Niño Southern Oscillation, an interannual variation in climate related to large-scale shifts in tropical atmospheric pressure manifested by El Niño and La Niña events.

Escapement: The number of fish that escape commercial or recreational fishing and return to spawn; these make up the expected breeding population.

Estuary: The mouth of a river where fresh and salt water meet and mix. Estuaries tend to be highly productive environments.

Eutrophication: A process by which over-enrichment of a water body with nutrients results in excessive plant growth and oxygen depletion.

Exotic species: See Alien species.

External threat (to protected areas): Something occurring outside the protected area boundary that threatens ecosystems and biodiversity within the protected area. For example, roads, urban development, tourist infrastructure, forestry, mining, agriculture.

Extinct: A species that no longer exists.

Extirpated: A species no longer existing in the wild locally, but occurring elsewhere.

Fecal coliform bacteria: Bacteria found in the intestinal tracts and feces of warm-blooded animals.

Fish population: A discrete group of fish that are of the same species and, in the case of salmon, spawn in the same stream.

Fish stock: A species, subspecies, geographical grouping, or other grouping of fish that is managed as a unit.

Flux: The amount of a substance, such as mercury, flowing from or over a given area per unit time.

Food chain/food web: The feeding relationships between species in a biotic community, from the producers (plants) up through various levels of consumers (animals). An example would be algae eaten by the water flea, which is eaten by a minnow, which is eaten by a trout, which is finally eaten by an eagle (or a person). Although often portrayed as a single chain of events, the reality is a web of interactions between species.

Fragmentation: Changing a continuous ecosystem, such as a forest, into smaller patches by disturbing the land. Fragmentation can be caused naturally, for example by fire, landslides, and trees falling in storms, and by humans during road building, forest harvesting, land clearing, and other activities.

Furans: See Dioxins and furans.

Greenhouse gases: A gas that absorbs and re-emits infrared radiation, warming the earth's surface and contributing to climate change. Greenhouse gases are released into the atmosphere by many naturally occurring processes and by human activities such as fossil fuel combustion, deforestation, agriculture, and industrial activity.

Gross domestic product (GDP): The total market value of all goods and services produced within a country during a specified period of time.

Groundfish: Fish that live on or near the bottom of the ocean.

Habitat: The place where a plant grows or an animal lives, and all the characteristics of that place, including climate, food, shelter, and others.

Halogenated compound: An organic compound that has one or more halogens, such as fluorine, chlorine, or bromine, substituted for hydrogen molecules. In a fully halogenated compound, all hydrogen has been replaced with chlorine or fluorine. The resulting compounds are generally less flammable but more toxic.

Impervious surface: A hard surface that prevents or slows the entry of rain and meltwater into the soil, causing water to run off the surface in greater quantities and at an increased rate of flow. Examples include roads, rooftops, and parking lots.

Internal threat (to protected areas): Something occurring inside the protected area boundary that threatens ecosystems and biodiversity within the protected area. For example, roads, visitor facilities, recreational use, exotic species, and activities that consume or extract resources.

Intertidal: The portion of seashore between the highest and lowest tides.

Introduced species: See alien species.

IPCC: Intergovernmental Panel on Climate Change: An international group of experts responsible for scientific assessments of global change.

Isostatic rebound: A geological process in which the earth's surface rises as stresses imposed by the weight of ice during the last glacial period are gradually released.

IUCN (World Conservation Union): The world's largest conservation network composed of 82 states, 111 government agencies, more than 800 nongovernmental organizations (NGOs), and some 10,000 scientists and experts from 181 countries in a unique worldwide partnership. The IUCN publishes the IUCN Red List of Threatened species, a global list of species at risk.

IUU catch: A fisheries catch that is illegal, unreported, and unregulated. It includes catches that are concealed or misreported as other species in violation of regulatory limits; unreported discards and recreational catches; and catches of species that authorities do not have a mandate to monitor.

Krummholz: Stunted, scrubby trees typical of windswept alpine regions close to treeline; from German for "crooked wood."

Landsat: Land Remote-sensing Satellite. A series of satellites that produce images of the earth from space.

Marine Ecosystem Classification: A part of the BC Ecoregion Classification system that further divides the benthic marine environment into 1201 ecounits based on seven physical parameters. There are 263 unique ecounit codes along the BC coast.

Marine protected area: A generic term used to describe an area of intertidal or subtidal terrain, together with its overlying or contiguous water and its associated flora and fauna, and historical and cultural features, which has been reserved by law to protect all or part of the habitats and/or species found within it. Note: The Canadian government also has specific, legislated designations called Marine Protected Areas. These provide a certain level of protection to an area.

MDF: Maximum Daily Flow, the highest recorded daily average discharge at a river gauging station (in cubic metres per second).

Mean trophic level: The average position in the food chain of species caught in a particular fishery. Mean trophic level of fisheries landings has been adopted internationally by the Convention on Biodiversity as an indicator of the integrity of marine ecosystems. See also Trophic level.

Nearshore: An indefinite zone extending seaward from the shoreline to well beyond the breaker zone.

Offshore: The zone beyond the nearshore zone where sediment motion induced by waves alone effectively ceases and where the influence of the sea bed on wave action is small in comparison with the effect of wind.

Orthophotograph: A photograph on which all distortions caused by tilt, relief, and perspective have been corrected.

Pathogen: A disease-causing agent, including bacteria, viruses, and fungi, usually microscopic in size.

PDO: Pacific Decadal Oscillation, a decadal-scale climate phenomenon related to changes in the geographic location of a persistent low-pressure centre over the Gulf of Alaska.

Pelagic: Organisms that live in open waters away from the bottom of aquatic ecosystems such as lakes, rivers, and the ocean.

Phylum: A major subdivision of classification in the animal kingdom.

Phytoplankton: Microscopic floating plants that live suspended in bodies of water and drift about because they cannot move by themselves or because they are too small or too weak to swim effectively against a current.

Pollutant: A contaminant whose concentration in the environment is high enough to result in deleterious effects.

Polygon: As used in computerized mapping (Geographical Information Systems), a stream of digitized points approximating the delineation (perimeter) of an area on a map. It is used to graphically represent the features of a defined area (e.g., an ecosystem or a type of land use) along with its associated attributes.

Protected area: A generic term used to describe areas of land and/or water that are protected in some way. The protected area may be called a park, an ecological reserve, or another name. The Canadian government also has specific, legislated designations called Protected Areas and Marine Protected Areas. These provide a certain level of protection to an area.

Protected unit: An area of protected land or protected ocean that is geographically continuous. For example, two protected areas that join one another make up one unit, and a protected area that occurs in four geographically distinct fragments makes up four units.

Receiving environment: The site or area where pollution or wastewater ends up after being discharged from a treatment facility or an outfall; usually a stream, river or ocean environment.

Recruitment: The number of individuals entering a population or a fishery each year.

Red listed species: A species that is legally designated as threatened or endangered under the provincial Wildlife Act, is extirpated, or is a candidates for such designation.

Regeneration: The replacement or renewal of a forest stand by natural or artificial means.

Riparian: Beside or along the bank of a stream or river.

SARA (Species At Risk Act): A federal act, proclaimed in June 2003, that applies to all federal lands in Canada, all wildlife species listed as being at risk, and their critical habitat.

Sensitive ecosystems: Ecosystems that are particularly vulnerable to human or natural impacts.

Smart growth: Environmentally sensitive land development with the goals of minimizing dependence on auto transportation, reducing air pollution, and making infrastructure investments more efficient.

Special Concern: A species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats (COSEWIC).

Species at risk: A wild species that is at risk of extinction or extirpation. The level of risk is identified, from highest to lowest, as endangered, threatened, and special concern. Both federal and provincial agencies designate species at risk, but only federal listings have legal protection under the Species at Risk Act (SARA).

Species: The classification for a group of organisms that is distinct from other such groups. Breeding within the group will produce fertile offspring.

SPSS: Statistical Package for the Social Sciences, a set of software utilities available from SPSS Inc.

Stewardship: Looking after something important and valuable that you do not own.

Stock: See Fish stock.

Subspecies: A formally named subdivision of species composed of geographically discrete populations that differ in appearance, behaviour, and/or genetics from other members of the species. Subspecies are capable of interbreeding with other members of their species.

Subtidal: The area extending below the lowest tidemark.

Taxon (pl: taxa): A group into which similar organisms are classified. For example, genus, species, or subspecies.

Taxonomy: Theory and practice of classifying living organisms.

TEQ: Toxicity equivalence, the international method of relating the toxicity of various dioxin/furan congeners to the toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin.

Teratogen: An agent or substance that may cause physical defects in the developing embryo or fetus when a pregnant female is exposed to that substance.

Terrestrial protected area: A generic term used to describe areas of land (including freshwater) that are protected in some way. The protected area may be called a park, an ecological reserve, or another name. The Canadian government also has specific, legislated designations called Protected Areas. These provide a certain level of protection to an area.

Threatened: A species likely to become endangered if limiting factors are not reversed (COSEWIC).

Terrain Resource Information Management Program (TRIM): A program to produce digital maps using the Universal Transverse Mercator coordinate system as the cartographic framework. TRIM mapping for BC consists of 7027 mapsheets covering the province at a scale of 1:20,000. Each mapsheet is precisely 12 minutes of longitude wide by 6 minutes of latitude high.

Total suspended solids (TSS): A measurement of the amount of solid matter in wastewater or effluent, usually expressed in parts per million.

Trophic: Pertaining to food or nutrition.

Trophic level (TL): The feeding position occupied by a certain organism in a food chain. Plants have a TL value of 1, herbivores (plant-eaters) have a TL of 2, and so on up the food chain. The value for top predators rarely exceeds 5.

Upland: Any land that occurs above the high tide mark at the seashore.

Urban sprawl: A pattern and pace of land development in which the rate of land consumed for urban or suburban purposes exceeds the rate of population growth using the developed land. Sprawl results in an inefficient and consumptive use of land and its associated resources.

Variety: Taxonomic classification, used primarily in plants, to indicate any kind of variation within a species.

Vulnerable: IUCN classification for species for which the best available evidence shows that it is facing a high risk of extinction in the wild.

Yellow List: Uncommon, common, declining, and increasing species—all species not included on the provincial Red or Blue lists, but tracked by BC Conservation Data Centre.